DETAILED ANALYSIS OF REGULATORY COMPLIANCE CONTROLS OF 1287 DWELLINGS VENTILATION SYSTEMS

Romuald Jobert [1], Gaëlle Guyot [*2]

[1]CETE de Lyon
48 rue St Théobald BP128
38081 L'Isle d'Abeau Cedex, France

*[1]Corresponding author:
gaelle.guyot@developpement-durable.gouv.fr

Note: the contact addresses may be re-arranged

ABSTRACT

Ventilation's historical goal has been to assure sufficient air change rates in buildings from a hygienic point of view. Regarding its potential impact on energy consumption, ventilation is being reconsidered. An important challenge for low energy buildings lies in the need to master airflows through the building envelope.

In this framework, the recent French energy performance (EP) regulation (2012) imposes envelope airtightness requirements for any new dwellings. As the dwelling airing is also governed by a 30-years-old regulation, this EP-regulation does not include any new requirement on ventilation rates.

In this context, actors in the building's sector are reflecting on the risk, with this generation of high performance airtight dwellings, of generating an unhealthy indoor air environment.

The "VIA-Qualité" project focuses on low energy, single-family dwellings. It proposes developing quality management (QM) approaches (ISO 9001) with the goal of increasing both on-site ventilation and indoor air quality. Such QM approaches, when applied to the individual home builder sector, appear to be promising. The benefits would be to: 1- Improve ventilation system performance, especially thanks to rigorous monitoring from conception to installation; 2- Limit indoor internal pollution sources, monitoring materials selection; 3- Increase final users understanding.

In France, the individual home builders sector accounts for more than 90 % of new single-family dwellings. Such QM approaches in envelope airtightness field are already being used by individual home builders, with respect to Annexe VII of the French EP-regulation. Feedback from these experiences shows that such approaches are both succesfull and affordable for either small or large individual home builder.

The first step in this project consists in increasing our knowledge of the actual performance of ventilation systems, once they have been installed and in-use in the buildings.

To this end, we analysed data from government building compliance regulatory controls, related to several laws, including energy performance and dwellings airing. Dysfunction analysis observed in a sample of 1287 dwellings allowed us to establish a more accurate picture of the quality of on-site ventilation systems. From a overall point of view, we observed that 68% of the single-family dwellings analysed do not comply with the regulation. A deeper analysis has allowed us to understand more specifically what are the underlying technical and organizational reasons for such results.

Firstly, this paper introduces the VIA-Qualité project objectives. Then, it rapidly presents the framework of French regulation compliance controls and the content of its underexploited database. The main part of this paper then presents the results of the detailed analysis of dysfunctions compilation observed on the sample, along 6 groups and 28 indicators. Finally, first proposals for ventilation installation improvement are presented.

KEYWORDS

Ventilation, airflow measurement, indoor air quality, regulatory checks, performance

1 INTRODUCTION

In order to insure a good indoor air quality, including a proper humidity level in buildings, adequate air change rate is necessary. On the other side, building energy performance requires to rethink of ventilation and air change rates, because of their impact on thermal losses:
1) New ventilation systems technologies, such as Demand-Controlled Ventilation (DCV) systems, aim at restricting airflows to the minimum level for healthy buildings. 2) Envelope airtightness treatment becomes essential, especially for low energy dwellings (Erhorn, 2008). Indeed, envelope air leakage entails thermal losses, but also modifies theoretical voluntary airflows circuits in building: airtight rooms may be short-circuited in case of other very leaky rooms. In France, the recent thermal regulation (RT2012) generalizes low energy dwellings and imposes envelope airtightness requirement for any new dwellings. For a single-family dwelling, the requirement is Q_{4Pa_Surf}=0.6 $m^3.h^{-1}.m^{-2}$, that is around n_{50}=2.3 h^{-1}.

This energy performance-regulation does not include any new requirement on ventilation rates. Dwellings airing are concerned by another 30 years old regulation (JO, 1982).
In this context, building's sector wonders about the risk for a generation of performing airtight dwellings to contribute to an unhealthy indoor air. Some questions are emerging in this way: are former regulations ventilation airflows in former regulations sufficient to provide a healthy indoor air in these new airtight dwellings ? For these dwellings, what are the consequences of dysfunctional-working ventilation installations ? What do we know exactly about the actual efficiency of those ventilation systems, once they are installed and in-use in the buildings ?

Some answers are given in recent research projects. The QUAD-BBC project (Boulanger, 2012) confirmed that envelope airtightness drives to a better indoor air quality, thanks to a better mastering of the theoretical airflows circuits in buildings. This project has also confirmed the need for increased airflows during cooking period.
Moreover, a growing number of actors, namely around the Healthvent project (Wargocki, 2012), agree about the idea that ventilation is not a panacea. To achieve a good indoor air quality, contributing to healthy buildings, reduce buildings pollutant sources is a priority.

The "VIA-Qualité" project focuses on low energy, single-family dwellings. It proposes developing quality management (QM) approaches (ISO 9001) with the goal of increasing both on-site ventilation and indoor air quality.

As a first step of this project, and in order to evaluate the ventilation system efficiency, we analyzed available data from regulation compliance controls, related to several regulations, including energy performance (RT2005 & 2012) and dwelling airing (1982-1983). Dysfunctions analysis of a 1287 dwellings sample allows us to establish an accurate picture of on-site ventilation systems quality. This original first analysis represents an essential step towards the final goal: find solutions to increase ventilation installation quality.

First, the paper presents quickly the "VIA-Qualité" project. Then, the framework of French regulation compliance controls and the content of this precious database. After that, it gives an overview of the analyzed sample. Finally, results of the detailed analysis of dysfunctions compilation are presented, leading to some proposals for ventilation installation improvement.

2 THE "VIA-QUALITE" PROJECT

The “VIA-Qualité” project (2013-2016) focuses on low energy, single-family dwellings. It proposes developing quality management (QM) approaches (ISO 9001) with the goal of increasing both on-site ventilation and indoor air quality. Such QM approaches, when applied to the individual home builder sector, appear to be promising. The benefits would be to: 1- Improve ventilation system performance, especially thanks to rigorous monitoring from conception to installation; 2- Limit indoor internal pollution sources, monitoring materials selection; 3- Increase final users understanding.

In France, the individual home builders sector accounts for more than 90 % of new single-family dwellings. Such QM approaches in envelope airtightness field are already being used by individual home builders, with respect to Annexe VII of the French EP-regulation. Feedback from these experiences shows that such approaches are both succesfull and affordable for either small or large individual home builder (Carrié R. et al, 2007) (Charrier S. et al, 2013).

The first step in this project consists in increasing our knowledge of the actual performance of ventilation systems, once they have been installed and in-use in the buildings. To this end, we analysed data from government building compliance regulatory controls, related to several laws, including energy performance and dwellings airing.

3 STUDY OF A SAMPLE OF BUILDING REGULATORY COMPLIANCE CHECKS

3.1 Building regulatory compliance checks: a precious source of field data

In France, building’s owner is legally responsible for the compliance with regulations: when asking for a building permit, he has to sign a commitment to comply with building regulations. Then, he must be able to prove that this building complies with these regulations.

Both during building construction and up to 3 years after commissioning, French authorities have the legal power to proceed to a regulatory compulsory check of any building. Controls are performed by sworn-in and specifically qualified government employees. Their qualification process includes technical and regulatory trainings, and a minimal number of controls performed under a senior employee supervision. The final qualification can be addressed only after a 3 years experience.

Several regulations are controlled, including energy performance and airing. The control is based on plans analysis, specifications analysis and calculations, on-site visit, visit at commissioning. Non-compliance with construction regulations is an offence, and controllers’ reports are sent to national authorities and to general attorney. Financial penalties may go up to 45k€ (75k€ if repeated). Prison term or banning from practicing may be decided. In general, no penal, no direct financial sanctions are sentenced, but the building’s owner must undertake remedial actions to comply with regulation, sometimes very costly. An extensive description of the control process is given in (Lecointre et al, 2009).

The French dwellings airing regulation (JO, 1982) requires a general and continuous airing system. It describes the compulsory general layouts of ventilation installation. It also sets exhaust airflows in each humid room, depending on the total number of rooms in the dwelling. Total airflows drive to around 0.5 h^{-1} global air change rate in the dwelling. This regulation has been modified in 1983 in order to reduce these airflows in case of demand-controlled ventilation system (DCV), for instance based on humidity. In this case, controls include also additional specific technical guidelines.

This regulatory compliance control includes two sections:

- “What can be seen and operated observation": control of the ventilation system installation, as well as of the whole ventilation equipments set;
- “Exhaust and supply airflows measurements»: check of airflow or pressure difference at air vents (global minimal airflow in dwelling, minimal airflow in kitchen, peak airflow in kitchen, peak airflow in other humid rooms).

The French construction technical regulation observatory (ORTEC) compiles these control data on both sections. In its last report, ORTEC published the following national statistics (CSTB, ORTEC, 2009):

- 50% of the controlled buildings do not meet the requirements in terms of ventilation mounting, with entails a system dysfunction;
- 43% of the controlled buildings do not comply with the regulatory airflow rates, especially concerning exhaust airflows that are insufficient for 36% of the buildings and excessive in 7%.

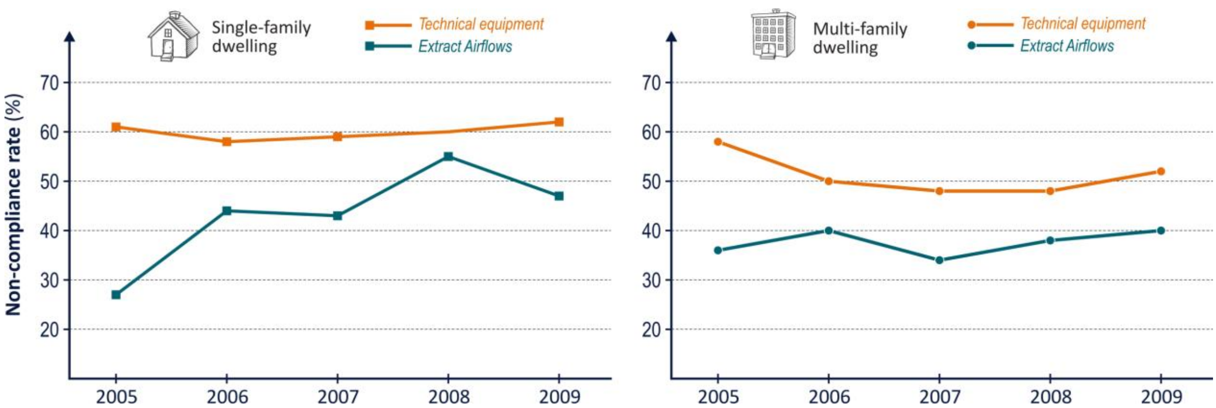

Figure 1: Annual distribution of non-compliance rates, for each type of dwelling, source: ORTEC, CSTB, 2009

However, these national published data are only statistical and mainly analyze “pass-or-fail” tests results. And yet, because comprehensive control reports fully describe all observed non-compliances, even when not related to the regulations, original data are far more detailed and include precise descriptions of the different causes, which affect ventilation performance.
As a result, beyond the regulatory aspect, these detailed reports constitute a potentially important technical database. This paper presents the first results using those data to explain the sources of on-site ventilation dysfunctions.

3.2 Description of the analyzed sample

We exhaustively analysed 373 control reports performed between 2008 and 2011, by the technical civil servants network of the Ministry in charge of the Construction’s sector. These 373 compliance checks reports concern 1287 dwellings, situated in different climate zones, and include by 88% of multi-family new dwellings (Figure 2).

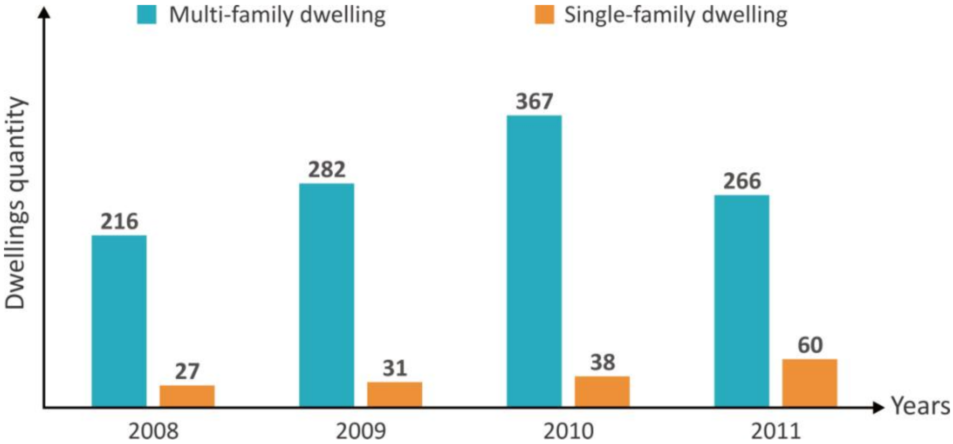

Figure 2: Dwelling type repartition analysed per year

Nearly all dwellings of the sample are equipped with simple exhaust mechanical ventilation. Humidity demand-controlled ventilation accounts for 74% of the sample. Balanced ventilation is found only in 10 single-family dwellings. This distribution (Figure 3) gives a good characterisation of the new dwellings stock in France, since the implementation of the 2005 thermal regulation (RT2005).

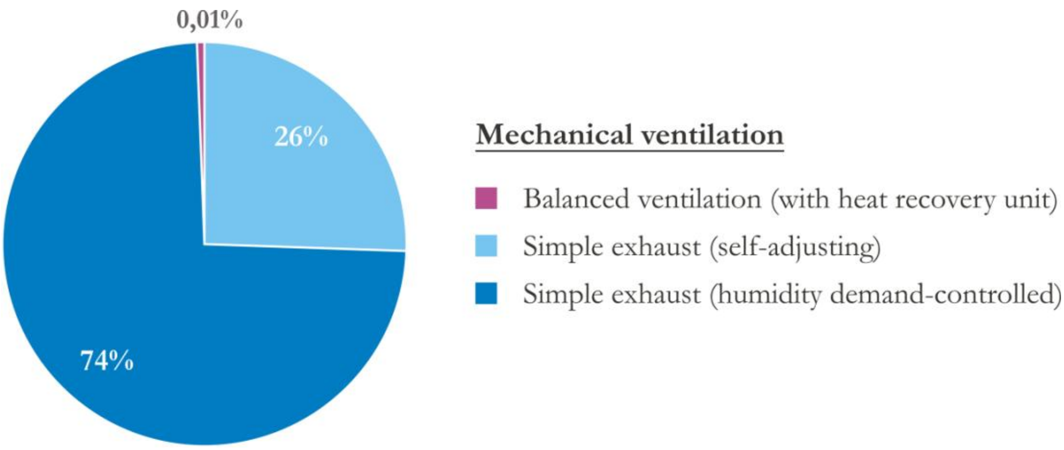

Figure 3: Ventilation system repartition in the analysed sample

The statistic analysis of this sample reveals that 604 dwellings out of 1287, that is 47% of the sample, do not comply with the airing regulation. It also means that 47% of the sample present at least one non-compliance remark. The non-compliance rate is 68% for single-family dwellings, and 44% for multi-family dwellings. These results confirm the national trend (CSTB, ORTEC, 2009).

Among non-complying dwellings, around 1/3 get only one non-compliance point, 1/3 two non-compliance points, and the last third obtain more than 3 non-compliance points.

4 ANALYSIS OF OBSERVED VENTILATION DYSFUNCTIONS

4.1 Global analysis

Based on the analysis of 373 control reports, the first part of the study consisted in drawing up and classifying all the dysfunctions observed during the controls into a 28 dysfunction points list. These 28 points have then been distributed into 6 representative categories for the main mechanical ventilation system elements: airflow/pressure (DCV) measurement, air inlet, air outlet, system configuration, ventilation fan, ducts (Figure 4), (Table1).

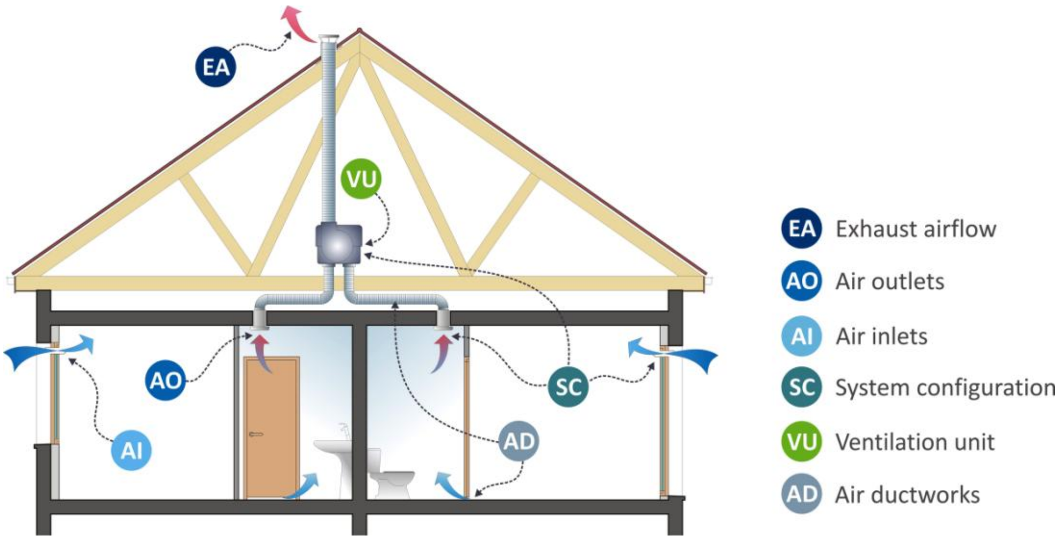

Figure 4: Dysfunctions classifying per category

Statistical analysis shows that the 604 non-complying dwellings account for 1246 non-compliance or dysfunctions points (Figure 5),. These points directly or indirectly contribute to a bad ventilation functioning, and also affect indoor air quality.

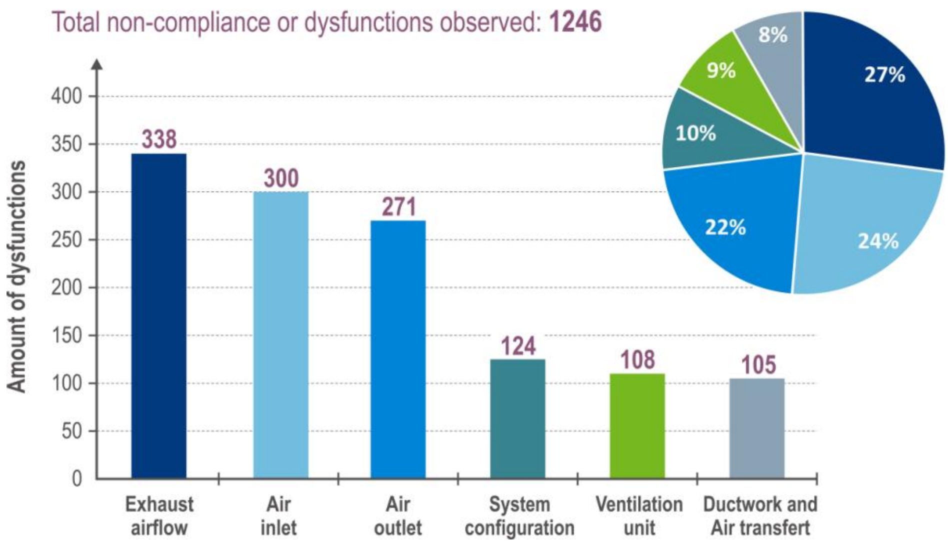

Figure 5: Number of non-compliance or dysfunctions items per category

We can notice that 46% dysfunctions are due to a bad quality of the ventilation mounting terminal devices, that are air inlets (24%) and air outlets (22%). As for air inlets, the most frequently observed dysfunctions are: lack of module, insufficient module quantity, and non-compliance with characteristics of the module (airflows).

And yet, on site, terminal devices comply with specific technical terms and conditions and are delivered with plans supplied by the main contractor. The problem lies with the quality of functional layouts mounting, often neglected.

The second important heading (around 1/3) concerns exhaust airflows. Among them, 85% non-compliance cases are due to insufficient minimal airflows, 15% to total excessive exhaust airflows. The frequent causes of these dysfunctions are: implementation of non-complying air outlet, non-adapted airflows regarding the size of the dwelling, bad quality of ventilation ducts mounting (air leakage and pressure losses).

Dysfunctions type		Amount	(%)
EA	**Air inlets**	**300**	**100**
EA1	Absence of air inlets modules	153	51
EA2	The Implementation of air inlets does not comply with prescribed rules and regulations	54	18
EA3	Presence of inlet air in a humid or service room	36	12
EA4	No mortises in window frames or incorrect size	28	9
EA5	Air inlet excess in the main rooms	17	6
EA6	Obturation of air inlets in one or more rooms	12	4
SA	**Air outlets**	**271**	**100**
SA1	The air outlets does not comply with regulation requirements	102	38
SA2	Control for changing peak flow missing or inaccessible	57	21
SA3	Dysfunction of air outlets equipped with presence detectors	41	15
SA4	Absence of air outlets in one or more rooms	39	14
SA5	Location of air outlets does not comply with regulation and technical requirements	32	12
QE	**Exhaust airflows**	**338**	**100**
QE1	The pressure measures at the air outlets are not correct	196	58
QE2	The exhaust airflows at the air outlets are not correct	142	42
SY	**System configuration**	**124**	**100**
SY1	The system configuration does not comply with the technical note requirements	74	60
SY2	Interversion of air inlet and air outlet	34	27
SY3	The system configuration does not comply with the standardized calculations of thermal regulations	16	13
GX	**Ventilation unit**	**108**	**100**
GX1	The warning signal which indicates ventilation failure is absent	55	51
GX2	The warning signal which indicates ventilation failure is not identified	34	31
GX3	Malfunction or failure of the ventilation unit	14	13
GX4	unsuitable Ventilation unit location and non-compliance with the acoustic requirements	4	4
GX5	Electrical protection group VMC is not independent of other circuit	1	1
CA	**Ductwork and air transfer**	**105**	**100**
CA1	Absence of transfer grids or doors undercut	49	47
CA2	Fouled air discharge in the attic	22	21
CA3	Extracting fouled air ducts are crushed or bent	17	16
CA4	Connecting ducts and duct fittings system are not airtight	17	16
Total of dysfunctions observed		**1246**	**100**

Table 1: Repartition and amount of dysfunctions observed by main mechanical ventilation system elements categories

4.2 Analysis of first reasons behind these dysfunctions

In most cases, observed dysfunctions are due to lack of attention at the mounting step. But they are also due to imperfections during the project managing process and during the decision chain whenever the ventilation installation process is concerned. Indeed, there is a real lack of continuity between program step, design, mounting, and also material and component furniture.

During the execution phase, the lack of ventilation installation quality is due to the actors' dispersion inside multiple technical lots. Thus, in the process of execution phase contracting procedures, ventilation is rarely defined as a specific lot. As a result, the ventilation different components installation is generally divided up among different building trades and no one is/feels responsible for the final result.

We also observed that ventilation installation verification is rarely planned during the construction phase, and that its control at commissioning is not systematic or most incomplete. Therefore, it appears that ventilation commissioning is an absolutely necessary step to ensure a well working installation upon receipt, with an in-use performance corresponding to the planned one. Recent guides (CETIAT, 2012) describe precisely these receipt procedures.
For further information on quality of ventilation systems in residential buildings, see also another French paper (Mouradian, 2013).
The on-going "VIA-Qualité" project will go further on reasons and solutions to improve ventilation systems quality once there are installed.

5 CONCLUSIONS

This analysis confirms that, even if adapted industrial solutions are available, ventilation system dysfunctions are very frequently observed in dwellings, which entails the reliability of these installations. Unfortunately, we found out that, just like in France, other countries (Boersta, 2012; Caillou, 2012) also observe that in-site ventilation system mounting is often far from the hoped quality.
This first analysis, based on French regulatory compliance controls and performed only on airing regulation (among 7 other regulations including energy performance), gives clear information about ventilation dysfunctions localisation and qualification. Up to now, only 1287 dwellings have been analysed. In 2013, an important project will harmonize data collection which goal will be to implement a robust database including all other information obtained from building regulation compliance checks.

very low energy dwellings (OQAI, 2011) even if some ongoing projects aim at increasing knowledge on this subject. But one thing is for sure: even if indoor pollution sources are minimized, the more airtight the dwellings will become, the more essential the need for guaranties on in-site ventilation installation quality will become. In this way, the French Effinergie+ label plans to reinforce ventilation controls, introducing ventilation airflows and duct leakage measurements at commissioning.

The main stake now consists in determining the ultimate causes for ventilation dysfunctions, and manage major projects to develop tools leading to better practices at every stage of the construction. For instance, many dysfunctions could be avoided through the implementation of quality management tools. With such tools, one could pretty easily, but efficiently, control ventilation system at each stage of the building construction: from design to installation, even including maintenance and final use.

6 ACKNOWLEDGEMENTS

The authors are very grateful to the French ministry for ecology, sustainable development, and energy (MEDDE), for their support during this study. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Ministry.

The "Via-Qualité" project is supported by ADEME, région Rhône-Alpes, and French ministry for ecology, sustainable development, and energy (MEDDE).

7 REFERENCES

Erhorn H., Erhorn-Kluttig H., Carrié F.R. (2008). *Airtightness requirements for high-performance buildings*. Conference paper, AIVC, Kyoto, Japan, 6 p.

Boulanger X. et al. (2012). *Lessons learned on ventilation systems from the IAQ calculations on tight energy performant buildings*. Conference paper, AIVC, Tightvent, Copenhague, Denmark, 7 p.

Wargocki P, Hartmann T. (2012). *Health-Based ventilation Guidelines for Europe*. HealthVent project, AIVC, Tightvent, Copenhague, Denmark.

W. Lecointre, R. Carrié and G. Guyot. (2009). *"France : Impact, compliance and control of legislation"*. Information paper P176, www.buildup.eu.

JO, *Arrêté du 24 mars 1982 consolidée relatif à l'aération des logements : aération générale ou permanente*. JO du 15 novembre 1983.

CSTB, Rapport de synthèse de l'ORTEC, Période 2005-2009. Rubrique "aération des logements", 2009.

Caré I., Chaffois P., Henry P. (2012). *Guide de bonnes pratiques des mesures de débit d'air sur site pour les installateurs de ventilation*. CETIAT, France, 49 p.

Mouradian L., Brière E. (2013). *Quality of ventilation systems in residential buildings - Status and perspectives in France*. In: proceedings of the AIVC workshop "Securing the quality of ventilation systems in residential buildings", Brussels.

Boersta A. (2012). *Residential ventilation system performance : outcomes of a field study in the Netherlands*. Conference paper, AIVC, Tightvent, Copenhague, Denmark, 7 p.

Caillou S. (2012). *Performances of ventilation systems : on site measurements related to energy efficiency,* comfort and health. Conference paper, AIVC, Tightvent, Copenhague, Denmark, 7 p.

Jobert R. (2012). "*La ventilation mécanique des bâtiments résidentiels neufs : État de l'art général - Analyse qualitative et technique des dysfonctionnements*". Mémoire professionnel, France, 125p.

Carrié R. et al. (2007). *Performance de la ventilation et du bâti*. Rapport final phase 1 et 2, Association air.h, France, 109 p.

Charrier S., Huet A., Biaunier J. (2013). *Airtightness quality management scheme in France: assessment after 5 years operation*. 34th AIVC Conference and 3rd TightVent Conference, Athens, Greece, 2013, 11 p.

Charrier S., Ponthieux J. (2013). *Control of airtightness quality management scheme in France: results, lessons and future developments*. 34th AIVC Conferenceand 3rd TightVent Conference, Athens, Greece, 2013, 11p.

OQAI Campagne sur 7 logements BBC

Effinergie association, www.effinergie.fr.