CONTROL OF AIRTIGHTNESS QUALITY MANAGEMENT SCHEME IN FRANCE: RESULTS, LESSONS AND FUTURE DEVELOPMENTS

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ABSTRACT

Since January 1st 2013, the French energy performance (EP) regulation requires building airtightness level to be justified to a lower-than-required value. These requirements represent an important change in the airtightness market. As a consequence, it is the State's responsibility to accompany this market evolution and to supervise the implementation of the quality in building airtightness. French regulation allows two ways to justify the airtightness value for the building envelope. Either the constructor performs systematic measurement on each building, or the constructor proves that a certified quality management approach is implemented.

The French State has created a specific national committee in order to evaluate the airtightness quality management schemes. The aim is to authorize constructors to justify the airtightness level of their buildings through a quality management approach. The CETE de Lyon is in charge of this committee.

In this framework, each constructor that has been certified by the committee must provide a yearly specific file. With this file, the constructor must prove the actual and yearlong application of its approach. Moreover, the committee implemented a first control campaign. It started in 2011 and ended at the end of 2012. This campaign had two goals. First, it aimed at checking the effective implementation of the quality management approach, on some buildings selected by the committee. Then, the committee wished to check the actual airtightness value of some buildings selected by the committee.

This paper will present a synthesis of the results and the lessons learnt from this control campaign. The first part will be dedicated to the analysis of the airtightness test results and to the difficulties encountered by civil servants while carrying out the control test. The second part will be dedicated to the analysis of the reality of airtightness quality management approach implementation.

The main results are 1) 75% of constructors comply with the required airtightness values, 2) but rarely, constructors fully comply with the quality management approach, 3) and constructors positively welcome the State control campaign.

The paper concludes with a synthesis of this campaign presented by a double label. The double label presents constructors results regarding levels measured and the analysis of their quality approach implementation. Finally, the paper ends with improvement proposals for the next control campaign. The State will continue to control certified constructors in two ways. Yearly file analysis will focus more on the reality of airtightness quality approach implementation. The control campaign will be maintained and will focus only on some certified constructors.

KEYWORDS

1 INTRODUCTION

Since January 1st 2013, the 2012 version of the French energy performance (EP) regulation (RT 2012) requires building airtightness level to be justified to a lower-than-required value. French regulation allows two ways to justify the airtightness value for the building envelope. Either the constructor performs systematic measurement on each building, or the constructor proves its certified quality management (QM) approach is implemented. The advantage of the QM approach is that it enables constructors to carry out measures on a restricted sample. Since 2006, the French State has implemented a committee (named the Annex VII committee) in charge of examining these approaches and proposing the certification. The certification allows constructors to justify the airtightness value of their buildings through a QM approach. The CETE de Lyon is in charge of this committee.

In the 2005 version of the French EP regulation (RT 2005), QM scheme was a constructors' voluntary approach. Since 2006, the French State has regularly certified RT2005 quality management approaches. The certification allows constructors to justify a better-than-default-value in their regular thermic calculation. Thus, constructors could use a 0.8 $m^3/h/m^2$ ($Q_{4PaSurf}$) airtightness value for their buildings envelope, instead of the 1.3 $m^3/h/m^2$ default value (for single dwellings).
In order to control the certified QM approaches, the French State planned two ways to control their real implementation. The first one is the submission by each certified constructor, of a yearly renewal file. This file is examined by the national committee presented above. The second way is a control campaign. This control campaign was carried out in its first version in 2011 and 2012. Leprince, (Leprince, 2011) describes key elements of a QM process and the control campaign process. Juricic (Juricic, 2012) presents partial results of the first year of the control campaign. The control campaign ended on December 2012.

This paper aims at presenting the control campaign process, its results and the conclusions of the whole campaign. It must be noted that RT 2005 certified approaches mainly concern single dwellings. The control campaign was therefore led on single dwellings exclusively.

This paper is organized as follows. Section 2 presents the control campaign on certified airtightness quality management approaches. Section 3 deals with quantitative results, that is to say values obtained by measures. Section 4 presents qualitative results, that is to say results of files analysis. Section 5 presents a global synthesis. Section 6 concludes with the evolutions for the next control campaign.

2 DESCRIPTION OF THE CONTROL CAMPAIGN ON AIRTIGHTNESS QUALITY MANAGEMENT PROCESS

This section presents the control campaign that was carried out.

2.1 QM approach and control principle

The underlying basis of an airtightness quality process is to implement a scheme that lasts from the genesis of the building project to the building commissioning. The QM approach is based on a precise description of "who-does-what-when-and-how". In addition, each step must be traceable and traced. The expected steps for such a process are:

- contracts between constructor and craftsmen, mentioning their involvement and fulfilment of the QM approach
- implementation of technical detailed drawings that will help craftsmen in the implementation
- craftsmen's training to the QM approach and to technical detailed drawings
- site supervision by a foreman, who must check in particular whether or not technical detailed drawings are properly applied on the construction site
- supervision documents of actions done in case of non-compliance
- detailed list of buildings applying the QM approach (address, type of construction, date of commissioning, measured value if a measure was carried out, etc.)

To justify its QM approach efficacy, a constructor must prove that airtightness measured values are lower than its QM approach airtightness limit value, on a sample of its production. With the RT 2005, these measurements were not necessarily done by an independent party (note that this part evolved with the RT2012).

The first control campaign, described in Leprince (Leprince, 2011), aimed at answering the following questions: are quality management certified approaches really implemented and fulfilled by constructors after receiving their certification? Indeed, before the implementation of the control campaign, the only official validation was based on file analysis, for initial requests or yearly certification renewal. With files inspection having a limited impact on constructors, the need for a control campaign became clear for the French State. The goal was for quality management approach certifications to be reliable and trusted.

The first control campaign was divided into two types of control:

- A quantitative control that consisted in measuring a part of the certified constructors' production. For that campaign, 5% of the yearly production of each constructor has been tested.
- A qualitative control that consisted in requiring all the documents produced in the frame of the quality approach for randomly selected buildings. For that campaign, 2% of the yearly production of each constructor has been tested.

For that first control campaign, 12 constructors have been controlled. This number corresponds to the number of certified constructors that had their certification since more than one year, at the date of the control campaign beginning (March 2011). The campaign represents 81 measures and 32 buildings qualitatively controlled. Figure 1 synthesizes numbers of qualitative and quantitative controls carried out for each constructor.

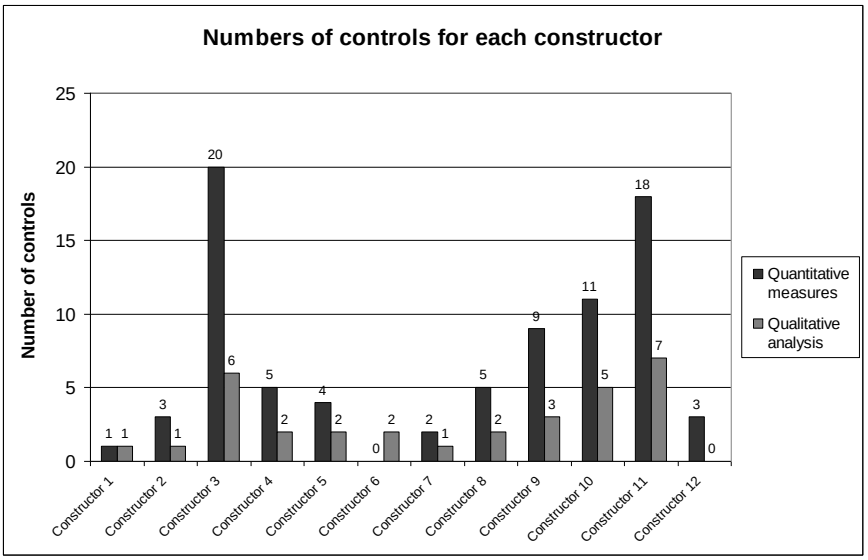

Figure 1: Numbers of qualitative and quantitative controls for each constructor

2.2 Quantitative control process

The quantitative control consisted in measuring a sample of the certified constructors' production. This control was carried out by independent state employees.

As described by Leprince (Leprince, 2011), to carry out the control campaign, the list of all constructions, which delivery is expected in the coming year, has been requested from the certified constructor. The list mentioned each construction's address, the approximate commissioning date and the name and telephone number of the future inhabitant as well as the foreman. A Microsoft Excel Solver determined how many measures had to be carried out for each constructor, in each geographical zone and by which controller (attached to a geographical zone). The same applied to the number of qualitative controls.

Requirements for that quantitative control were the same as the ones used for the yearly files control in RT 2005. For each constructor, 85% of measured values had to be below the reference value (0.8 $m^3/h/m^2$) and 100% below the default value (1,3 $m^3/h/m^2$).

2.3 Qualitative control process

The qualitative control consisted in checking the actual implementation of the certified QM approaches. In that goal, some tracing documents were requested for a set number of buildings.

The qualitative control analysed whether the documents were given or not. If files were not given, this allowed the controller to suppose that the certified QM approach was not implemented in its entirety. The five requested documents were the followings:

- List of the companies working on the site
- Contracts or subcontracts signed by all companies working on the site (that should include an airtightness statement)
- Craftsmen's certificate of training
- Site supervision documents (that must prove the fulfilment for each step of the certified QM approach)

- Tracing documents of the actions in case of non-compliance (corrective treatments, compliance of corrective treatments, results of corrections, etc.).

Each controlled building was selected by state controllers.

3 RESULTS ON QUANTITATIVE CONTROL

This section presents the results of the measures carried out on a sample of certified constructors' production. Organisational results and measured results are presented.

3.1 Not a such unexpected control

One of the goals of the quantitative controls led by neutral controllers was to verify actual airtightness value on buildings. Indeed, in RT 2005, measures were not necessarily neutral. As a consequence the random selection of tested buildings by constructors was not guaranteed. The quantitative control by independent controllers enabled one to guarantee measures and certified QM approaches reliability. In that framework, controlled buildings had to be selected by the controller.

Results of the quantitative control are the following. For 66% of constructors, the choice of the buildings was either made by the constructor, or by the controller. But in both cases, the appointment date was known soon enough (from 1 to 3 weeks before) so that constructors could organize the improvement of the tested building airtightness. This was noticed by controllers during the quantitative control, who regularly (25% of the tested buildings) encountered fresh silicon joint or polyurethane foam in inappropriate places.

Thus, this behaviour slightly modifies two aspects of the QM process. First, that behaviour reveals a more curative approach than a global approach of airtightness that must last during the whole building implementation period. Then, this puts into perspective the measured results, as they were obtained on cured buildings. Results cannot be relevant of the airtightness average value of constructors' production.
However, we should note that 4 constructors (25% of controlled ones) left the entire choice of the tested buildings to the controller. Furthermore, 2 constructors partly influenced the choice (half of tested buildings decided by controller and the other half by the constructor itself).

One of the firsts lessons of that quantitative control is that the actual unexpected in situ control is difficult to implement. A second lesson is that QM process underlined philosophy is not yet assimilated by all constructors. That philosophy lies on considering airtightness as a global issue that must be taken into account from the genesis of a project to the building commissioning. The complementary philosophy is the dissemination of good practices.

3.2 75% of constructors comply with requirements

81 measures have been carried out on 11 certified constructors' production. No measures have been carried out for one of the constructors. Figure 2 presents global results, all controlled constructors together.

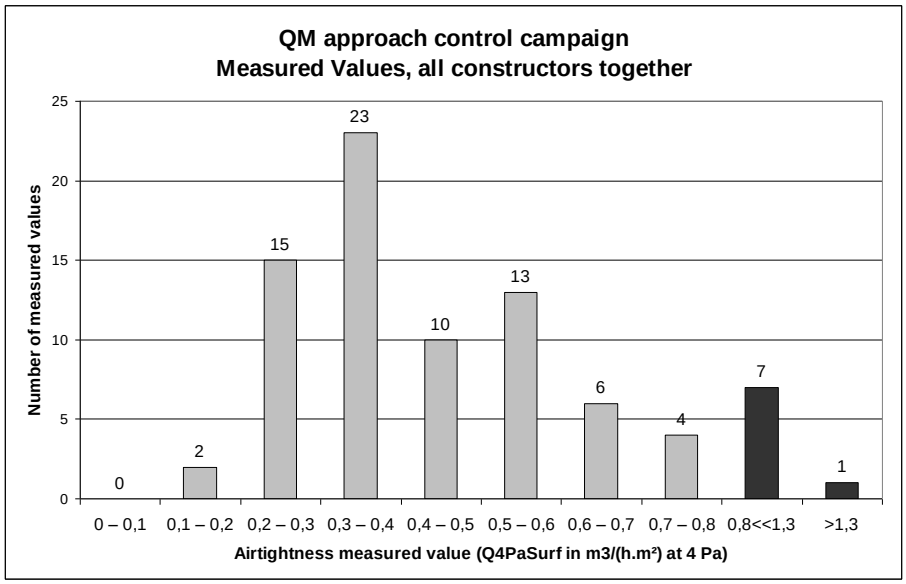

Figure 2: Measured values on 11 certified constructors

72% of measured values are between 0.2 and 0.6 $m^3/h/m^2$. These values are good results as they are far from the limit value (0.8 $m^3/h/m^2$). This tendency gives a comfortable margin in regards to the limit value. 90% of measured values are under the limit value and 10% are over.

This chart tab has been done for each constructor in order to control if their results comply with regulation.
9 constructors comply with regulation and they do not exceed the limit value, excepted for one constructor, for which 5 % (1/20) of its controlled production is between reference (0.8 $m^3/(h.m^2)$ at 4Pa) and default value (1.3 $m^3/(h.m^2)$), what remains in accordance with regulation.
2 constructors do not comply with the regulation. The first one presents only 78% (14/18) of measured values below reference value. The second one presents 78% (8/9) of measured values below reference value and 11% (1/9) above default value.

3.3 Synthesis of quantitative results: quantitative results label

In order to synthesize the control campaign results, the choice has been made to represent that synthesis into a double label. One part represents quantitative control results and the other part the qualitative control results.

For the quantitative label, a distinction has been made between different levels of conformity. Indeed, as the quantitative control was based on the constructors' production, some of them have been more controlled than others, speaking in absolute numbers (from 1 to 20 tested dwellings). Therefore, it is natural that good results on "large" constructors are statistically more reliable than results on "small" constructors, who have been concerned by fewer measures.

Thus the quantitative results label is divided into 5 levels presented below:

- Conformity, a lot of measures: All buildings comply with regulation and more than 10 buildings have been tested.

- Conformity, few measures: All buildings comply with regulation but fewer than 5 buildings have been tested.
- Conformity, word of warning: All buildings comply with regulation but measured values are close to the limit value.
- Non conformity: The measured values do not comply with the regulation that imposes 85% under referent value (0.8 $m^3/(h.m^2)$) and 100 % below default value (1.3 $m^3/(h.m^2)$).
- No data available.

The synthesis of the quantitative control results is displayed in the quantitative results label below (Figure 3).

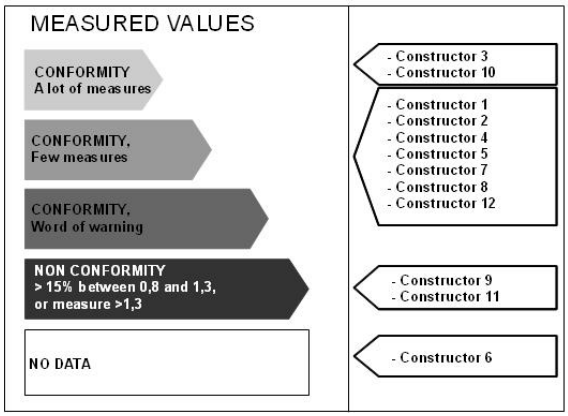

Figure 3: Label presenting quantitative control results

4 RESULTS ON QUALITATIVE CAMPAIGN

This section presents the qualitative control results. As in previous section, two points of view synthesize the results. One evaluation focuses on constructors' behaviour and control campaign welcome. The other evaluation focuses on factual results of the qualitative file analysis.

4.1 A welcomed procedure

Concerning the constructors' welcome of the control campaign, it must be noted that half of constructors did welcome the control campaign. Indeed, most of them were pioneers of airtightness QM approaches and developed that approach in order to enhance the quality in construction. Therefore, they welcomed the control campaign in order to prove their certified approaches reliability.

4.2 A different importance for each inspected file

As presented in section 2.2, 5 files were requested so that the QM approach actual implementation is verified on some randomly selected buildings. For that first control campaign, the qualitative control was only based on verifying whether each file had been given or not. The content of each file has not been evaluated.

In order to analyze and compare constructors' results, the five files have not been considered with the same degree of importance. Thus, site supervision documents and actions in case of non-compliance documents were considered of major importance, whereas craftsmen's training certificates were considered of minor importance. Nevertheless, this does not mean

that craftsmen's training is not important. It only means that, if that document was missing for a constructor and if the site supervision document was missing for another, we considered that the QM approach was less reliable for the second case than for the first one.

4.3 Results on the qualitative control

32 buildings have been qualitatively controlled, on 11 constructors' production. One constructor has not been evaluated. Figure 4 presents global results, all controlled constructors together. For each expected file, it presents whether the file has been given, has not been given or has been partially given, that is to say documents have been given but not for all craftsmen.

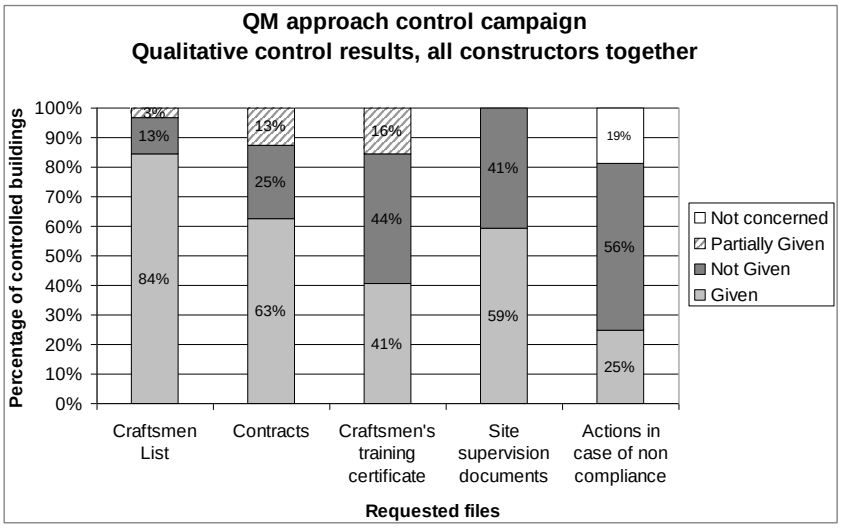

Figure 4: Results of the qualitative controls

Figure 4 shows that the list of craftsmen working on the construction site was very often given, as well as craftsmen's contracts. Then, we can note that 44% of craftsmen's training certificate has not been given. This can reveal some laxity in the constructor involvement to disseminate good practices. This is already noted as a global tendency in RT 2012 QM approaches and is revealing of the constructors' approach, who seems to consider that good practices dissemination is not helpful in obtaining airtightness values that comply with regulation.

Figure 4 also shows that 41% of site supervision documents were missing. This fact is particularly problematic. Indeed, as they are the documents that will enable the constructor to detect any non-compliance with its certified approach, these site supervision documents are one of the quality management process keystones. For instance, these documents trace the construction implementation and its compliance with technical detailed drawings. Their absence can directly lead to a non-compliant airtightness measured value.
Furthermore, 56% of the documents that should trace the implemented actions in case of a non-compliant point with the certified QM approach were not given. This represents 18 buildings (for 32 tested buildings). Among these 18 buildings, 10 buildings concerned only two constructors. Finally, 6 constructors failed in giving the file tracing the action in case of non-compliance. As the previous point, this file is essential for the QM process. Indeed, this document enables the constructor to ensure that every gap with the QM approach will be treated.

4.4 Synthesis on qualitative control: qualitative results label

As explained in section 3.3, the synthesis of the qualitative control is represented in a qualitative results label. The qualitative label is divided into 5 levels representing the fulfillment of the QM approach. These 5 levels take into consideration (1) the above results on files supplying, (2) the importance accorded to each file and described in section 4.2, (3) and the controllers' feeling on each constructor, about the collaboration and cooperation they showed.

Thus the qualitative results label is divided into 5 levels presented below:

- QM approach entirely fulfilled: all the required files have been given and comply with QM approach. The constructor expressed positive collaboration and cooperation.
- QM approach fulfilled some files missing: the majority of requested files have been given, particularly supervision files. The craftsmen's training certificates are missing. The given files comply with the QM approach. The constructor expressed positive collaboration and cooperation.
- QM approach fulfilled, but half of the documents are missing: files given comply with the QM approach. A more active collaboration was expected for that control campaign.
- Key files are missing: Site supervising and actions in case of non-compliance documents are missing. A more active collaboration was expected for that control campaign.
- No data: the committee did not receive the controller's analysis (internal issue).

The synthesis of the qualitative control is illustrated in the below qualitative results label (Figure 5).

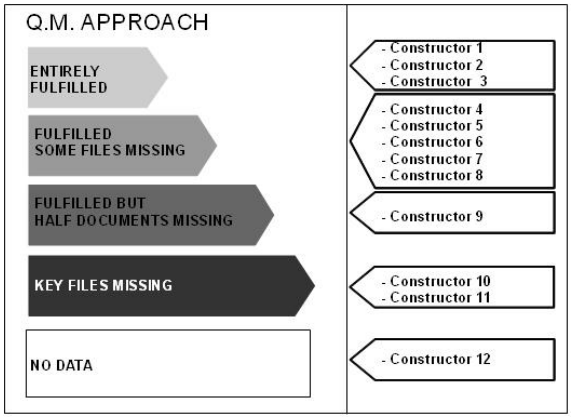

Figure 5: Label presenting the qualitative control results

We note that 25 % of controlled constructors seem to actually comply with their certified QM approach. 75% seems to apply in quasi-entirety their QM approach. 3 constructors seem to have real difficulty in applying QM approach.

5 GLOBAL SYNTHESIS: CONTROL RESULTS DOUBLE LABEL

The synthesis of the control campaign is represented by a double label, composed by both quantitative and qualitative results. The final label is presented in Figure 6.

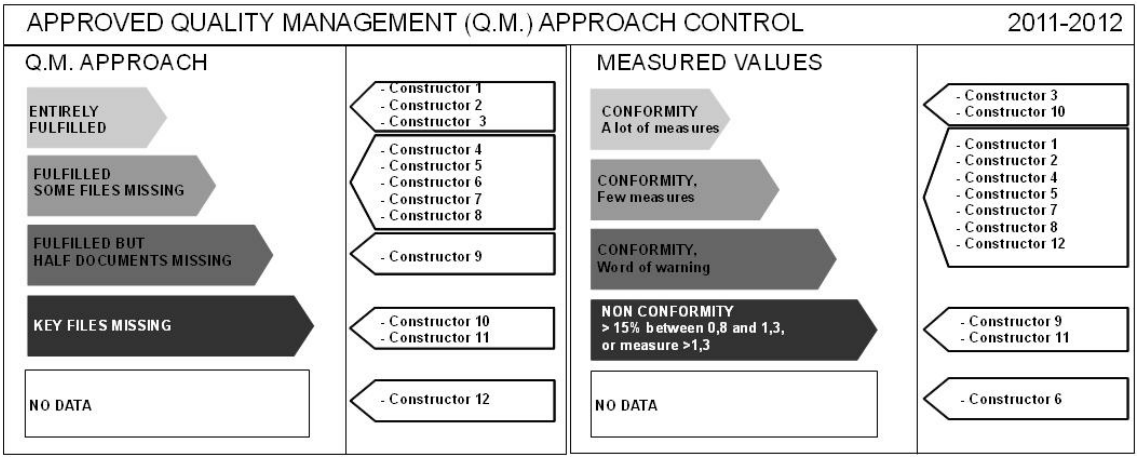

Figure 6: Control results double label

With this double label, we can note that 2 constructors came across difficulty in fulfilling the QM approach (constructors 9 and 11) and this was confirmed by measured values.
We can notice, comparing this double label with Figure 1, that the 3 constructors who have the worst results are at the same time among those who were the most controlled. However, we can also notice that constructor 3 was one of the two most controlled constructors, and its results are good. These tendencies allow us to assert that for the next control campaign, it might be fairer to define an equal controlled buildings volume for every controlled constructor.

This kind of double label has been implemented for each controlled constructor. Each constructor received a synthesis of that first control campaign, mentioning (1) its personal double label and the global label mixing all controlled constructors, (2) personal positive and negative points revealed by the control campaign and (3) the ways to improve the implementation and the measured results of their QM.

6 CONCLUSION

The control campaign has been launched in order to affirm certified QM approach reliability. As a first control campaign, the objectives were educational with a view of accompanying constructors in the application of their certified QM approach. The main conclusions of that first control campaign are that 2 constructors (on 12 controlled constructors) have difficulty in fulfilling the QM approach. The results for the other constructors are encouraging. Other main lessons learnt from that first campaign are the followings:

- We noticed a deviance in QM approach by constructors. For half of them, they seem to have a more curative approach than a global one.
- Results must be used cautiously, as some constructors have been more controlled (absolute number of controls) than others.

Thus, some improvements were put forward by controllers, for the next control campaign:

- Try to implement an actual non-expected quantitative control, if possible
- The volume of controls should be the same for each controlled constructor.
- Control only of a sample of constructors. Controlled constructors would be chosen by committee, regarding their initial file, yearly renewal file and the potential complaints.

As described in Charrier (Charrier, 2013), QM processes have become of growing interest with the RT 2012, since 2012. This growing interest and the positive results of the first QM

approach control campaign require a reliable management of the committee and of certifications. In that purpose, control campaign on certified quality management approaches is maintained and a second one will be carried out, in 2013 and 2014. The second version of the control campaign should take into consideration all the above points related by controllers (or part of). Then, the principle of qualitative and quantitative controls should be maintained. However, in situ control is a key element for certified QM approach reliability. Thus, qualitative control could be replaced by an in situ audit. This could be divided into two sequences: first, a quality management approach audit based on ISO 19001 procedures, and then, a construction site visits with craftsmen and superintendents meetings.

Then, we must bear in mind that:

- One quality management approach is certified for collective dwellings, and the QM approach committee expects more requests for such buildings in 2014.
- Ventilation ducts airtightness quality management approaches are expected, as the RT 2012 enables them.

As a consequence, it seems essential to affirm the certified quality management approach reliability. This can essentially be made thanks to the control campaign and, if possible, with more in situ controls so that constructors are aware of their responsibilities.

7 ACKNOWLEDGEMENTS

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