IMPROVING ENVELOPE AIRTIGHTNESS : RESULTS OF A PILOT STUDY ON 31 HOUSES

Karine Guillot, Daniel Limoges, François Rémi Carrié

Centre d'Etudes Techniques de l'Equipement de Lyon
46 rue Saint Théobald
F – 38081 L'Isle d'Abeau Cedex, France

ABSTRACT

This paper presents the results of a field study conducted on 31 houses owned by a French social housing management body. The central objective of our investigation was to propose and evaluate rehabilitation scenarios to improve the envelope airtightness. For this, pre- and post- envelope leakage measurements were performed together with infrared thermography analyses. In parallel, the occupants were interviewed to better understand their interaction with the thermal functions and what their feeling was about the thermal comfort and indoor quality in their homes. These detailed investigations performed on 8 houses showed that the airtightness could be significantly improved (median at 0.3 $m^3/h/m^2$ at 4 Pa), and that the refurbishment lead to better thermal comfort.

KEYWORDS

air leakage, envelope, survey, infrared thermography, thermal performance, low-income housing

INTRODUCTION

This work is part of a broader research program supported by ADEME and EDF that aims at evaluating the significance of envelope leakage and at improving the airtightness of new and existing buildings [1][3][4].

In this particular study, OPAC de l'Ain (social housing management body) decided to evaluate the significance of envelope leakage of a group of 31 semi-detached electrically heated houses, to better understand its interactions with occupants' comfort and energy use, and to propose, conduct, and evaluate retrofitting actions.

This paper concentrates on the evaluation of the overall process. More information regarding the pre-characterization and definition of scenarios can be found in an earlier paper [2].

PROJECT PHASES

The project phases are briefly described herebelow :

Phase I **(**Winter 2001-2002) entailed pre-characterization and definition of refurbishment scenarios. It included :

- Airtightness tests on 8 residences and identification of major leak sites with IR thermography
- Heating energy use monitoring during 2 winter months in 9 residences
- Temperature and humidity monitoring at different locations during 2 winter in 9 residences
- Airflow rate measurements at Air Terminal Devices (ATDs)

Phase II (2003) consisted in implementing the retrofitting measures on site. CETE was involved in the assistance to building owner to raise awareness among the companies involved, and a few spot controls.

Phase III (winter 2003-2004) consisted in analysing and evaluating the overall process based on post-characterization of envelope leakage, indoor environment monitoring, and questionnaires among occupants.

SUMMARY OF REFURSBISHMENT MEASURES AND COST

Retrofit actions have been derived for each type of defect, based on guidelines detailed in reference [1] and interactions with professionals. Most actions consist in sealing cracks with mastic joints or insulation foam. The total cost per house was of 2 100 Euros including 1 300 Euros for the replacement of windows. In other words, the extra cost due to the manual sealing of cracks is 800 Euros.

(a)

(b)

(c)

(d)

(e)

Figure 1. Examples of refurbishment measures. (a) replacement of windows. (b) Replacement of undercut joint and joint around the opening. (c) Replacement of the garage lock. (d) Injection of insulation foam to close the passageways to the air gap in the wall. (e) Insulation foam behind the plug boxes in cold walls.

MAJOR RESULTS OF PHASE III

Envelope airtightness improvement

The pre- and post- envelope leakage measurement results are synthesized in Figure 2. The value of I_4 ranged between 0.63 and 1.64 $m^3/h/m^2$, with a median at 1.15 $m^3/h/m^2$. Except for one, the envelopes are considerably leakier than the reference used in the French building code (0.8 $m^3/h/m^2$). After refurbishment, the I_4 ranged between 0.67 and 1.29 $m^3/h/m^2$, with a median at 0.79 $m^3/h/m^2$. The median of the airtightness improvement is 0.3 $m^3/h/m^2$.

The IR thermography analyses have shown that significant improvement at window frame-opening interfaces, garage doors, access panels to attic. However, significant leakage remained at window frame-wall interfaces, and electrical boards and conduits.

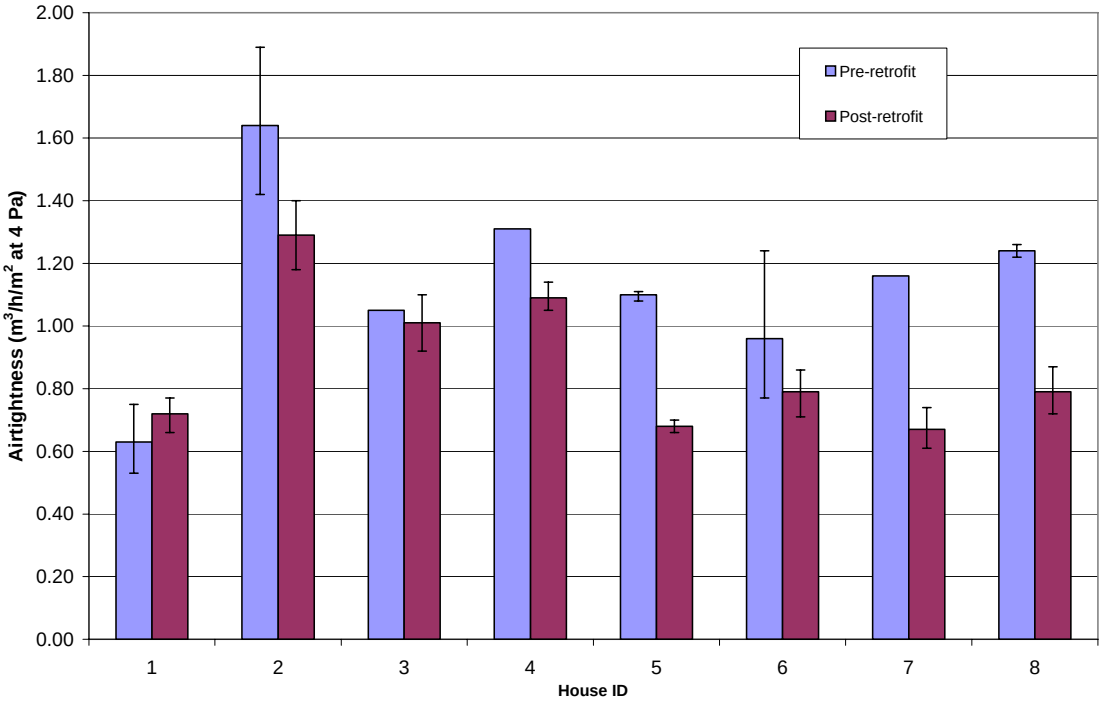

Figure 2. Pre- and post- airtightness measurements in m^3/h per m^2 of cold walls (except lower floor) at 4 Pa.

Evaluation of potential energy use reduction

The uncontrolled airflow rate due to envelope leakage has been evaluated using a simplified model developed by CSTB similar to the calculation procedures adopted in the former energy performance regulation (Th-G, 1991). Figure 3 and Figure 4 show that the additional unwanted airflow rate ranges from –4% up to +18% and leads to heating energy losses ranging from –215 up to 1320 kWh. The gain on the ventilation energy losses is estimated to be of 10% on average for a heating season.

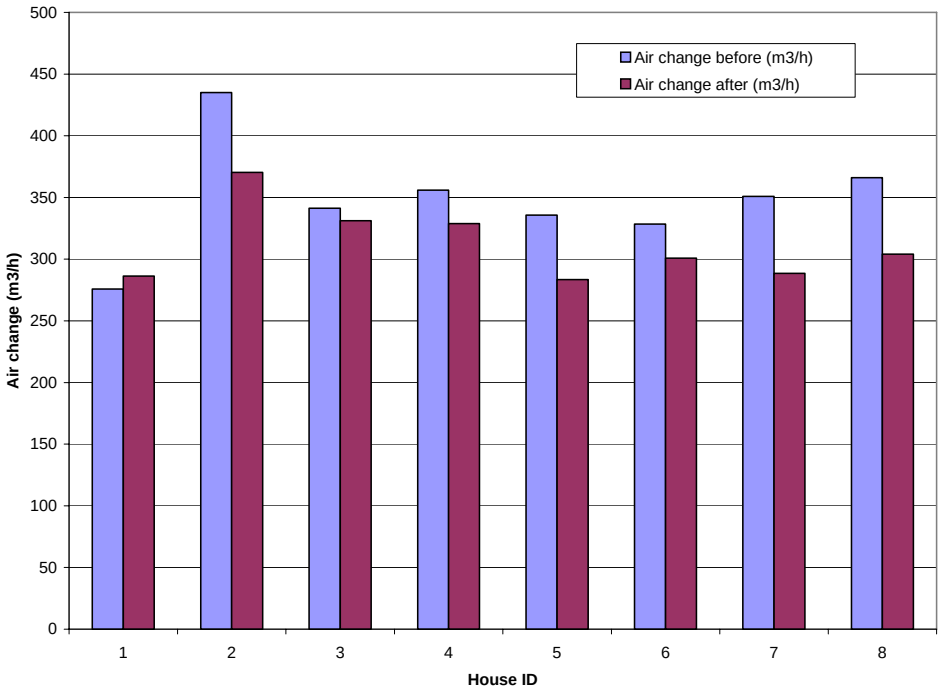

Figure 3. Estimates of air change rate before and after refurbishment.

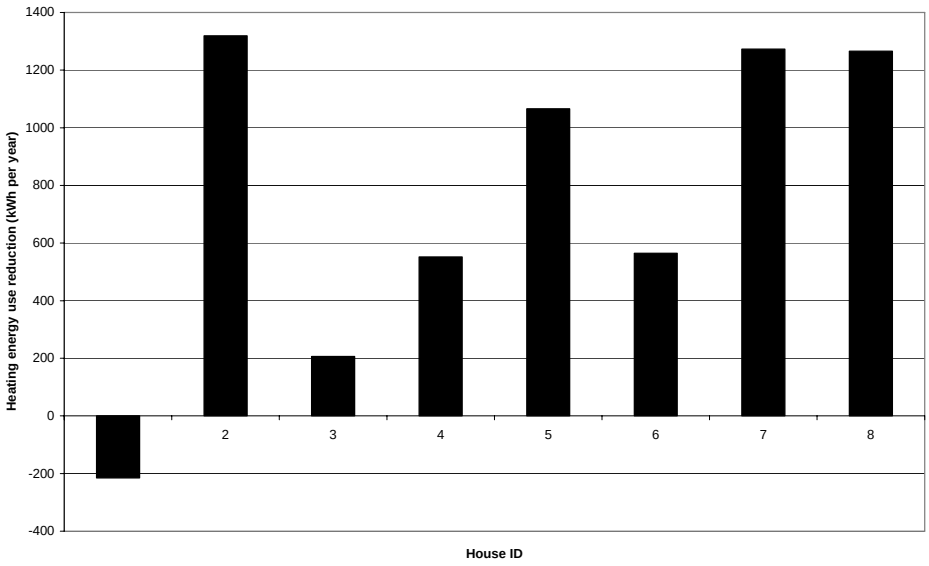

Figure 4. Estimates of heating energy use reduction on a heating season (2500 degree days).

Occupants' behaviour and acceptance, perceived thermal comfort

The energy savings results should be used with care as the calculation does not take into account the effect of occupants' behaviour. The analysis of our questionnaires shows that the occupants have not changed their thermostat setting before and after retrofitting and that they continue window airing during long time periods even during cold days, despite the information given during the experimentation.

The replacement of the windows has been seen as a very positive measure by the occupants. This major work has shaded the considerable efforts made by the contractors on manual sealing. Interviews among the occupants show that the measures that are perceived most effective are : first, the replacement of windows; second, the electrical boards and garage doors. On the other hand, 5 of them are disappointed with the work performed on the main door. In fact, in many cases, it was so distorted that the new sealing joints could not be effective.

All occupants interviewed were satisfied with the progress made with regard to thermal comfort. They all described this progress in terms of reduction of cold draughts and/or feeling of cold.

Tips and traps

Here is a list of major tips and traps that have been identified in this study.

Tips :

- carefully locate cracks
- check the ventilation system performance and define retrofit actions to be undertaken if necessary
- discuss the definition of the work together with the contractors and manufacturers
- carefully define the requirements to the contractors regarding the products to apply and their installation

Traps :

- degradation of materials too significant, making any measure ineffective
- reluctance to undertake work with costly side effects (ex. skirting boards)
- economic context making unattractive manual sealing for the contractors
- lack of awareness, need for skilled labour

Ways of progress and reproducibility

Several ways of progress have been identified :

- to raise the principal barriers, in particular, by integrating the concern of airtightness in all the actions of maintenance – maintenance of real estate, by writing clear requirements ;
- to develop pedagogy and the communication near the professionals and occupants on the objectives of ventilation, the principle of mechanical ventilation, the possibilities of saving energy while satisfying comfort, in order to avoid behaviours detrimental to energy and comfort ;
- to stimulate the quality of the work in order to put forward good practice and skilled labour, which remains an key aspect in the construction process ;
- finally, at research level, to improve knowledge on the contribution of the various components and connections of the envelope to air leakage. This more precise

knowledge could make it possible to concentrate efforts towards the trades most concerned.

The reproducibility of this action on a large scale highly depends on progress made regarding those questions, as well as the awareness of building owners and managers, contractors, and occupants.

CONCLUSION

The objective of this experimentation was to test the feasibility of reducing envelope leakage in existing buildings. Globally, the evaluation of this project shows that simple measures can be implemented with success. It also shows that sealing cracks can result in significant energy savings and better comfort. These issues are all the more important as the buildings is highly insulated with energy efficient equipment. This is why the improvement of envelope air tightness is an important question that should be addressed in the context of the energy performance of buildings directive; rehabilitation projects (mentioned in particular in article 6 of the EPBD) should take into account the benefits of reducing envelope leakage.

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