The Cambbridge research project, gathering a Belgian construction company (Jacques Delens s.a.) and a university (UCL)

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Abstract

The world of construction is subject to growing requirements regarding the quality of buildings. The delivery of an envelope must be accompanied by an EPB certificate. In addition, contractors are requiring levels of performance that are higher than those imposed by the regulation: BREEAM, LEED or passive certifications. These certifications are based on theoretical calculations and do not provide a guarantee of real building performance. However contractors aspire to obtain better guarantees regarding buildings real performance. The increase in the number of airtightness tests performed reflects this concern. In 2014, one out of every three new dwellings is subject to air-tightness measures in the Flemish Region and one in five in the Walloon Region of Belgium.

In that context, there is a growing interest in the concept of 'energy performance contracting' defined by the European Directive 2012/27/EU as "a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial savings".

Being able to confirm that the obligation of result is achievable and achieved, is the new challenge faced by the construction industry.

Research institutes want to consolidate sets of achievable reference values for energy performance indicators and to compare them with theoretical predicted values. They also intend to extend their expertise regarding the analysis of data collected by in situ testing. Education institutions that forms architect engineers intend to promote their training in the processing of data collected through building monitoring, as a significant amount of those engineers are involved in the management of building stocks, thereby confronted to large samples of measured data.

Universities are also committed to serve the community. By promoting the quality of workmanship in the construction sector as well as the quality of the building stock, a guarantee of quality is provided to the consumers. New job opportunities could also be created in the measurement of building performances and the analysis of monitored data.

In that context, Cambbridge research project is gathering a Belgian construction company (Jacques Delens s.a.) and a university (UCL) in order to develop reliable methods that can be applied on site during the construction phase in order to assess the actual performance of buildings at a moment when it can still be improved to reach the target without entailing over costs. The proposed measurement process includes 5 days of pre monitoring during which the building can be occupied or not, followed by 9 days monitoring without occupancy. It is a tradeoff between the constraints of the construction work, that do not allow too much time to be spend for the tests, and constraints related to building physics.

The research implies parallel experiments on identical building units, to check the reliability of a method based the observation of floating indoor temperature compared to a conventional co heating test. The relevancy of the placement of internal insulation on party walls is also checked as it allows the indoor temperature to reach higher values and as it reduces heat losses to neighboring units. As quasi-stationary co-heating has so far been limited to the winter months, it is crucial to expand the time window for HLC assessment by developing summer approaches. Methods based on the observation of floating indoor temperature meet that goal. Such innovative measurements methods try to take advantage of solar gains effects instead of avoiding them.

Keywords: Building Physics; Parameters Identification; Experimental Design

1. The context

The world of construction is subject to growing requirements regarding the energy performance of buildings. The EU countries' drive towards a more energy efficient future has produced substantial benefits for Europeans. For instance, new buildings consume half the energy they did in the 1980s.

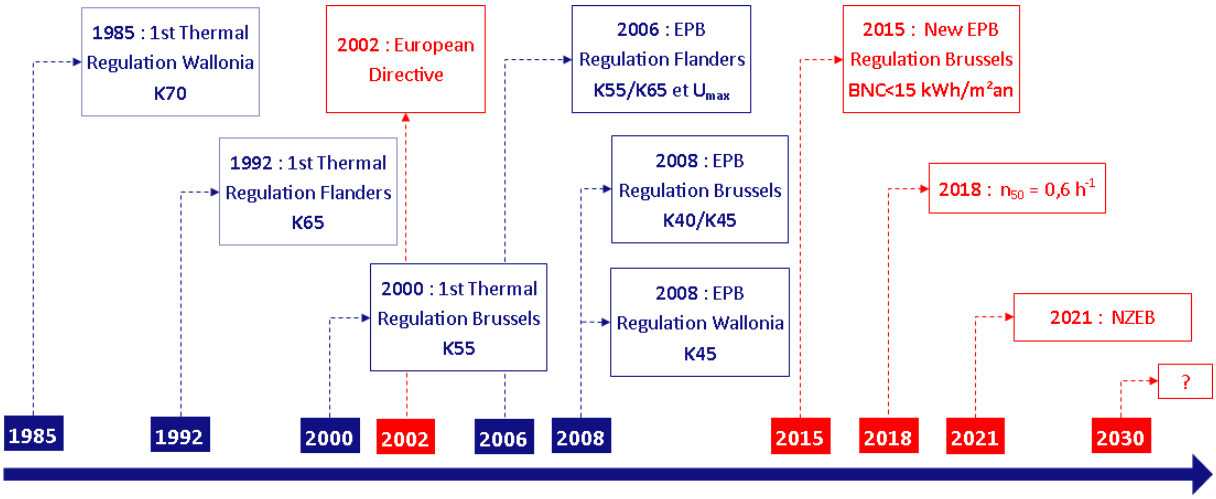


Fig. 1: Evolution of Belgian regulations regarding building thermal performance of building since 1985.

The evolution of building energy performance requirements in Belgium since 1985 is illustrated on fig.1. Requirements regarding the insulation level (K) evolved from K70 to an actual value of K35, which means that the requirements in terms of average U value decreased from 0.70 to 0.35 W/m2-K, for a house whose volume to envelope area ratio equals 1m. Requirements were more recently expressed in terms of building net heating requirement (BNC) in kWh/m2.

A green building certification (BREEAM, LEED etc.) is an increasingly common requirement for global corporate occupiers. According to the World Green Building Trends survey, over a third of companies surveyed expect to have at least 60% of their building projects certified green by 2018 (Sutherland J., 2016).

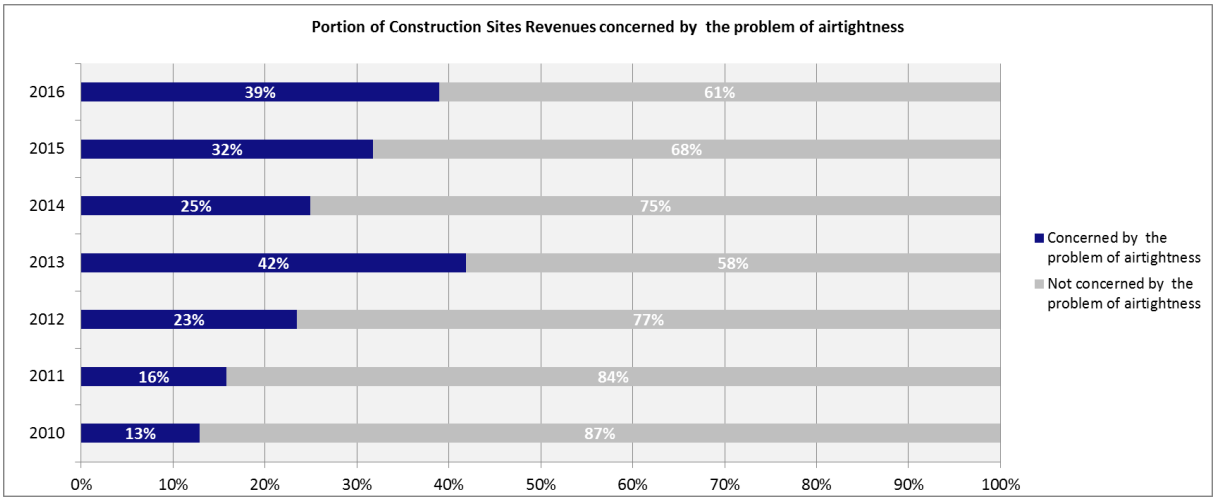


Fig. 2: Portion of Construction Sites Revenues concerned by the problem of airtightness among Jacques Delens s.a. Construction sites located in Belgium.

Airtightness testing has, since the 1980's, been used to test high-performance housing. Recently there has been a growing interest in testing the airtightness of large buildings (fig. 2).

2. The research project

The performance of a building envelope is characterized by its insulation level and by its airtightness level. Two gaps regarding the performance assessment can be identified (fig. 3, left):

- Compliance checks and labelling of the buildings thermal performance are done in the design phase by calculating the theoretical energy use, but on site measurement of the building actual performance is not performed. When measurements are performed, they can reveal a significant gap with theoretically designed targets.

- Airtightness measurement is performed through a blower door test when high-performance is required. While the test is performed with an obligation of result, typically n50 < 0.6 h-1, there is no tool available at the design stage to try and predict whether this mandatory result is achievable.

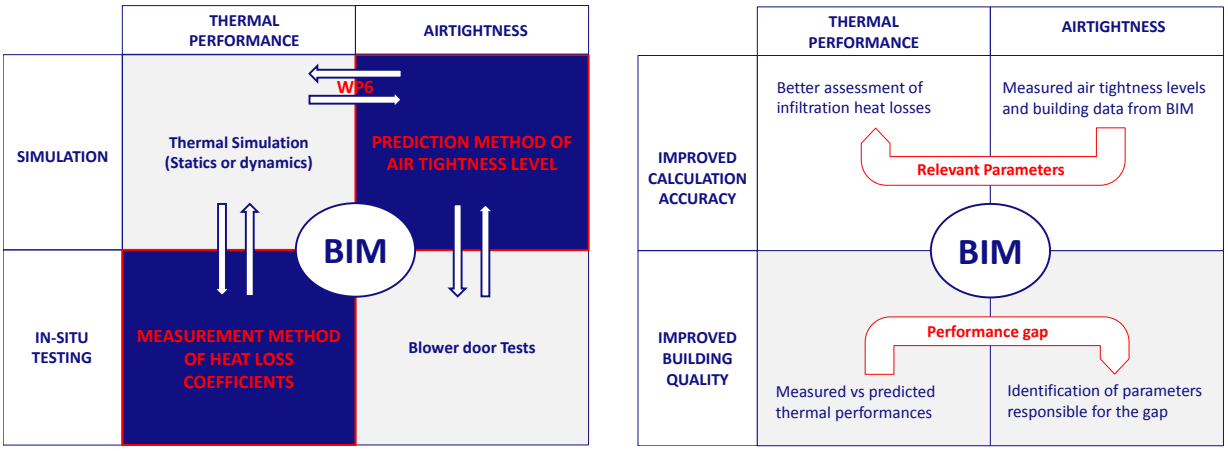


Fig. 3: Identifying the gaps regarding the performance assessment of building envelopes (left). Interaction between thermal performance assessment and airtightness assessment (right).

As a consequence, construction companies spend a lot of effort to ensure a high building airtightness level and they tend to exaggerate, reaching values sometimes lower than 0.3 h-1 for the n50, while the required value is 0.6 h-1. Part of that effort could be spend for other fields of interest regarding building energy performance.

As thermal performance is only assessed on a theoretical basis, there is no procedures and commonly accepted targets enabling construction companies to demonstrate the benefit related to the quality level of their workmanship. Aspirations regarding the thermal performance of buildings are limited to compliance and do not go beyond.

Construction companies also operate in a competitive world where Building Information Modeling (BIM) is changing the way projects are constructed. This emerging practice offers new opportunities regarding the exchange and the analysis of data.

The Cambbridge research project is aiming at:

- Providing and testing methods for in situ checking of the building thermal performance at the building construction stage.
- Performing pressurization tests under different boundary conditions in order to perform statistical correlations enabling further predictions of buildings airtightness levels on the basis of their design data.

Both tasks are interacting with each other, as illustrated on fig. 3 (right):

- Correlations enabling air tightness prediction are useful to disaggregate the global Heat Loss Coefficient (HLC) into its components related to infiltration and wall transmission.
- The differences observed between the predicted and the measured HLC could be correlated with the building parameters in order to better understand the specific causes of the performance gaps.

3. The measurement of the thermal performance

Jacques Delens s.a. Company is active in the construction, refurbishing and restoration of residential and commercial buildings, including large multi-storey buildings where identical construction units can be tested in parallel, allowing the comparison of different measurement procedures (fig. 4). A difficulty is that the heat loss may occur through any party elements of construction (such as party walls, party floors, etc.), and it is not possible to gain access to all of the surrounding apartments or spaces when undertaking the tests.



Fig. 4: Measurements sites: student dwellings in Etterbeek (up left), appartments in Neder-over-Heembeek, Brussels (up right), experimental setup inside the units with insulation panels, electric radiator, air temperature sensors and pyranometer on the terrasse (down left), weather station located on the roof (down right).

The measurement process is targeting the identification of the unit façade HLC. The proposed measurement process includes 5 days of pre monitoring during which the building can be occupied or not, followed by 9 days monitoring without occupancy.

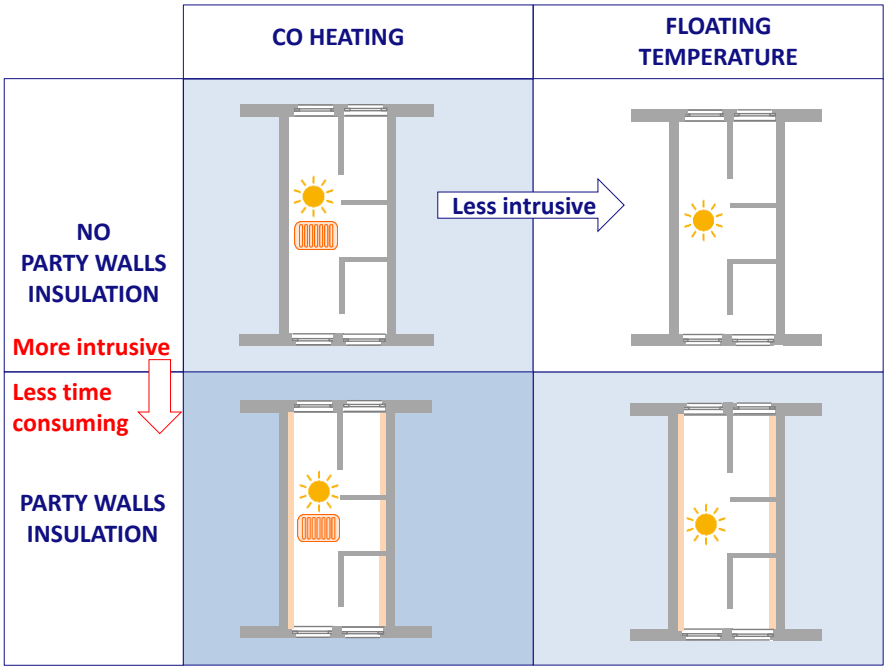


Fig. 5: Different boundary conditions and heat sources for the measurement of the Heat Loss Coefficient.

The measurements are performed on South oriented units in summertime. The ventilation system is off. Ventilation inlets/outlets are sealed. Solar protections are removed when possible. Different boundary conditions and heat sources are considered (fig. 5):

- Co-heating test without insulation panels covering the internal party walls
- Floating temperature without insulation panels covering the internal party walls
- Co-heating test with internal party walls covered by insulation panels
- Floating temperature with internal party walls covered by insulation panels.

The covering of party walls by insulation panels reduces the thermal mass effect and allows internal temperatures to reach higher levels than those observed in the uninsulated units (fig. 6).

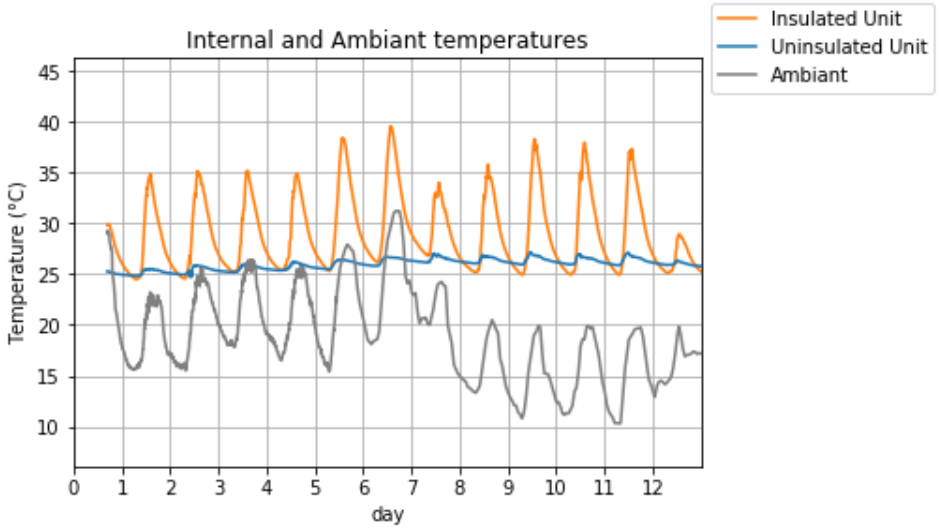


Fig. 6: Measured floating temperatures with and without insulation panels covering the party walls (St Pierre & Paul, Brussels, 2017/08/23-2017/09/04).

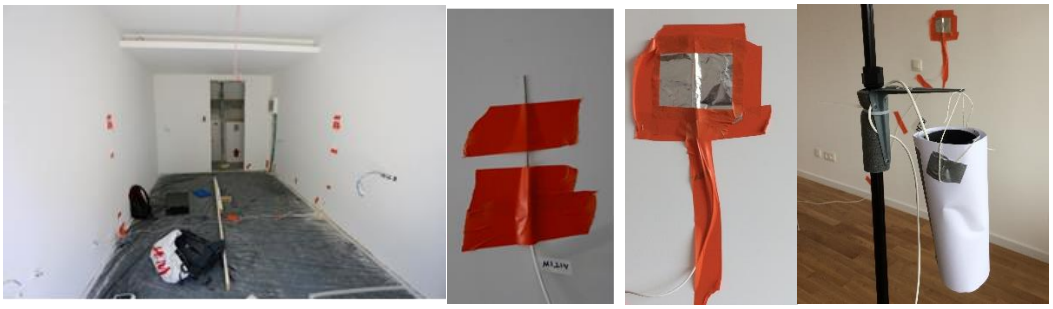


Fig. 7: Temperature measurement at the interface of insulation layer before placement of insulation panels (left,center left) and at the surface of uninsulated walls (center right) and air temperature probe (right)..

Temperature probes are installed at the interface of the insulation layers. An analysis of the results from the first experiment highlighted the importance of measuring the temperatures at the surface of the party walls that are not covered by insulation panels (fig. 7).

The first analysis of the results in the insulated units suggests that the HLC of the façade can be estimated both by the floating temperature method and by co-heating test. The effect of internal thermal bridges between the units is more important for the co-heating test method.

4. Conclusions

CAM(B)BRIDGE is a research and innovation project aiming to address the building performance gap regarding the airtightness level as well as the thermal performance. The project is implementing a method to control the thermal quality of the building envelope in the construction phase, as well as a method of assessment of the building airtightness in the design phase.

The co-heating method is traditionally used in winter to measure the building HLC. It is crucial to expand the time window for HLC assessment by developing summer approaches additionally to the traditional co-heating method. A better understanding of the solar gains and mass thermal effects could help to develop innovative measurements methods trying to take advantage of solar gains effects instead of avoiding them. A better assessment of solar gains could also benefit to the traditional co-heating method.

The values of the predicted and measured HLC should be collected in a data base. The discrepancies between predicted and measured HLC could then be correlated to building data, in order to acquire additional detailed understanding of buildings. The field test would then not only able to ascertain the difference between measured and expected HLC (the “performance gap”) but such correlations could enable to understand the specific causes of the difference. This approach is called "closing the loop" and should be the ultimate goal of the process, allowing the construction sector to improve the quality of building performance.

5. Acknowledgements

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