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ASSESSMENT OF BUILDING ENERGY PERFORMANCE THROUGH ON SITE MEASUREMENTS

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ABSTRACT

The certification of Building Energy Performance is currently based on theoretical calculations. However, in a context of growing interest in the concept of 'energy performance contracting' as defined by the European Directive 2012/27/EU, the construction industry is facing new challenges regarding the measurement and verification of building real performances.

In that context, UCL is developing methods, in collaboration with Jacques Delens s.a., 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. 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. The proposed measurement process includes 9 days monitoring without occupancy.

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.

KEY WORDS: Building Physics; Parameters Identification; Experimental Design.

1. INTRODUCTION

The world of construction is subject to growing requirements regarding the energy performance of buildings. The concept of 'energy performance contracting' as defined by the European Directive 2012/27/EU, entails new challenges regarding the measurement and verification of building real thermal performances.

Compliance checks and labelling of the buildings thermal performance are currently 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 [1]. However, in-depth building fabric thermal performance tests undertaken on passive dwellings in the UK revealed that the case study dwellings performed very close to that predicted [2].

The building envelope thermal performance can be characterized by its Heat Loss Coefficient, HLC. The HLC can be measured through a process called "co-heating" or "Whole Building Aggregate Heat Loss Test". In order for the method to be effective, there must be a significant internal-external temperature difference, a difference of at least 10 K is recommended [3-5]. This has restricted practical application of the co-heating test to the winter heating season [6, 7].

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The testing in building with attached spaces (such as semi-detached, terraced or apartment buildings) presents a problem in co-heating, particularly if it is not possible to access the adjacent space in order to install sensors [8].

The inaccuracies in calculating the solar gain have a large impact on the reproducibility of the measurement of HLC, particularly in the summer months. A reliable evaluation of solar heat gains and solar heat loads is thus a crucial issue for the determination of the HLC [3]. The validation of dynamic simulation models must be considered in order to test their reliability to predict indoor temperature profiles in presence of significant solar heat gains.

Such a validation exercise was conducted in the framework of AIE EBC Annex 58 research program [9, 10]. It was based of full scale experiments performed by the Fraunhofer Institute in Holzkirchen, Germany in 2013 and 2014. The experiment provided well documented data sets enabling modelers to validate their simulation models and to explain the discrepancies observed between theoretically predicted and measured building responses [11].

2. THE MEASUREMENT OF THE THERMAL PERFORMANCE

CAM(B)BRIDGE is a research and innovation project aiming to characterize the building thermal performance through measurements. The project is developed in collaboration with Jacques Delens s.a. Company. It is implementing a method to control the thermal quality of the building envelope in the construction phase, through a 9 days monitoring period without occupancy. As the co-heating method is traditionally used in winter to measure the building HLC, the project is aiming at expanding the time window for HLC assessment by developing summer approaches additionally to the traditional co-heating method.

Jacques Delens s.a. Company, partner of the project, is active in the construction, refurbishing and restoration of residential and commercial buildings, including large multi-story buildings. This allows to realize parallel experiments on identical building units in order to check the reliability of a method based the observation of floating indoor temperature, compared to a conventional co heating test (fig. 1).

The study focuses on the determination of the overall heat loss coefficient of the external facades, without considering the external floor heat losses nor the roof heat losses. As the apartment units chosen for the experiment are all located under the roof, the covering of their ceilings by insulation panels allows to focus on the determination of the external facades heat loss coefficient. A difficulty is related to the presence of common walls and floors shared by adjacent units as it is not possible to gain access to all of the surrounding apartments or spaces when undertaking the tests. The difficulty is overcome by the placement of internal insulation panels on party walls and on party floor, as well as on the ceiling (fig. 1). The setup allows to reach higher values of internal temperatures and it reduces the heat losses to neighbouring units.

The proposed measurement process includes 9 days monitoring without occupancy. 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. 2):

- 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.

Fig. 1 Measurements sites: student dwellings in Etterbeek (up left), apartments in Neder-over-Heembeek, Brussels (up right), experimental setup inside the units with insulation panels, electric radiator, internal air temperature sensors and external pyranometer on the balcony (down left), weather station located on the roof (down right).

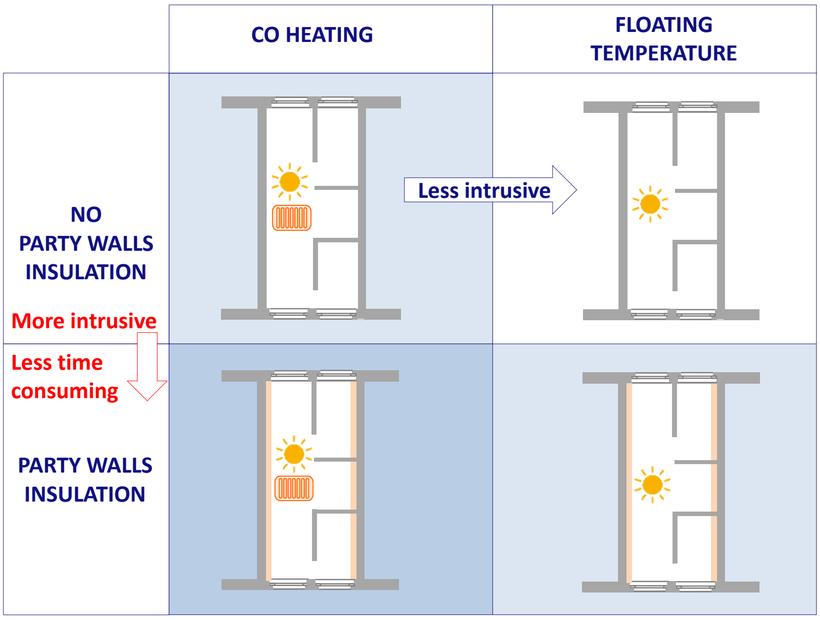

Fig. 2 Different boundary conditions and heat sources for the measurement of the Heat Loss Coefficient.

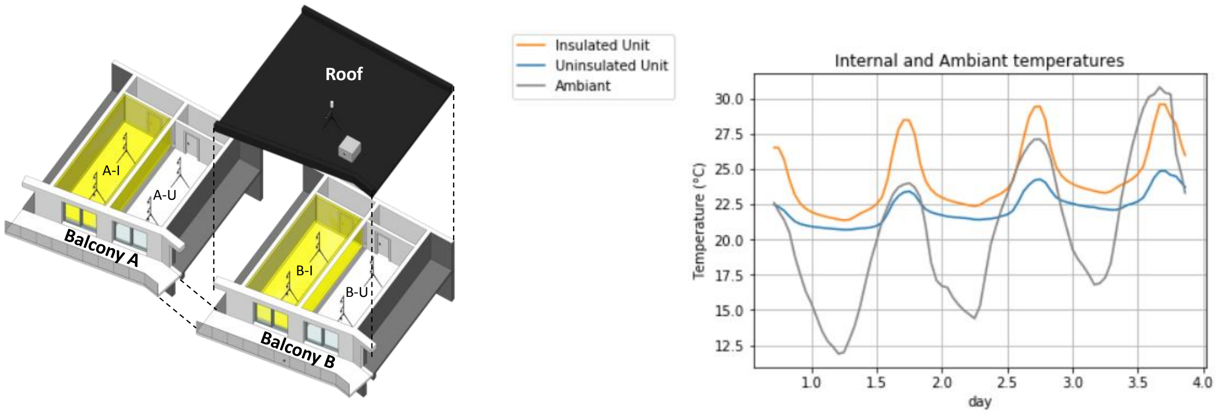

Fig. 3 Measured floating temperatures with and without insulation panels covering the party walls of identical units (Printemps, Brussels, 2017/05/24-2017/05/27).

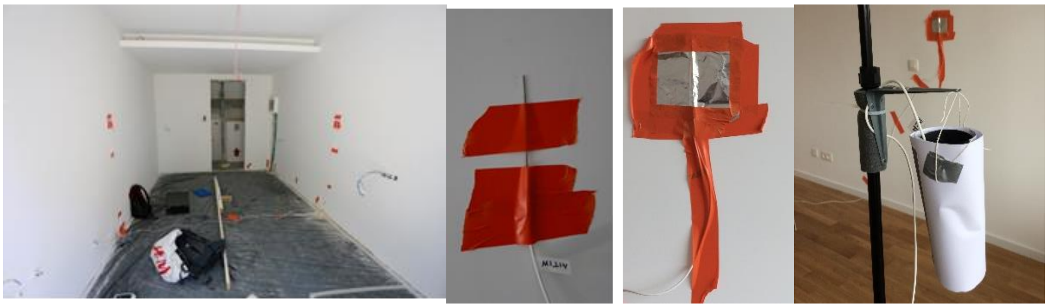

Fig. 4 Temperature measurement at the interface of insulation layer before placement of insulation panels (left, center left) and at the surface of uninsulated walls (center right) and air temperature probe (right).

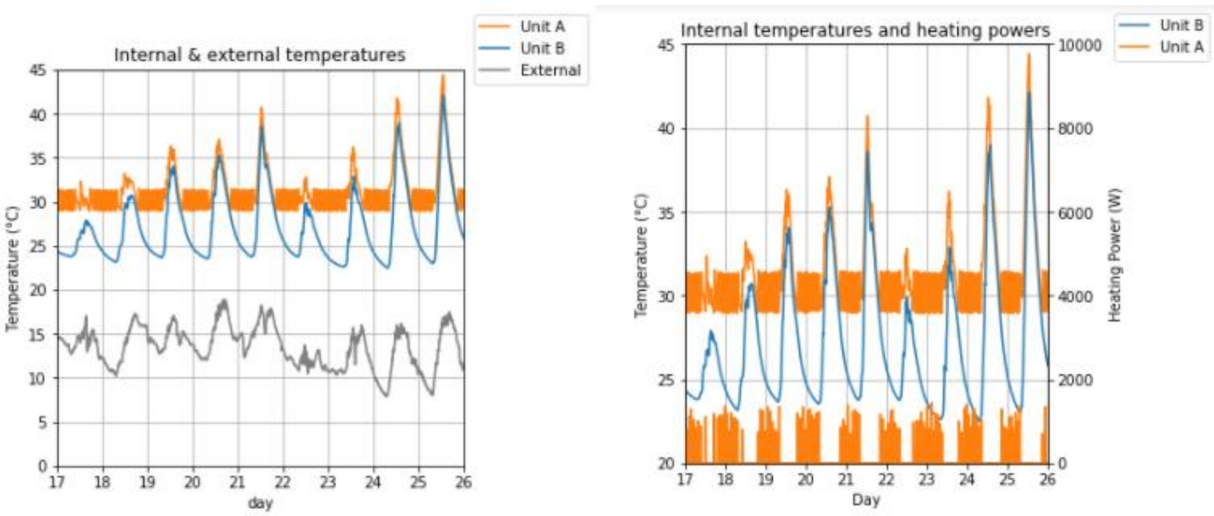

Fig. 5 Evolution of external temperature and internal temperatures in two identical units provided with inside insulation, B in floating temperature mode and A in co-heating mode (left) and evolution of the heating power in unit A (right).

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. 3).

The analysis of the results from a first experiment highlighted the importance of measuring the temperatures at the surface of the party walls that are not covered by insulation panels. Temperature probes are installed at the interface of the insulation layers (fig. 4).

The heat balance is assessed by considering the daily average data measured in parallel on two identical units, one in floating temperature mode, and the other in co-heating mode (fig.6). Both units are submitted to solar heat gains while only one is co-heated. A correlation can be drawn between the difference of internal temperatures and the heat power from the co-heating, in order to get an estimation of the HLC (fig.7). The heat balance includes the estimation of the heat exchanges through the insulation panels covering the party walls.

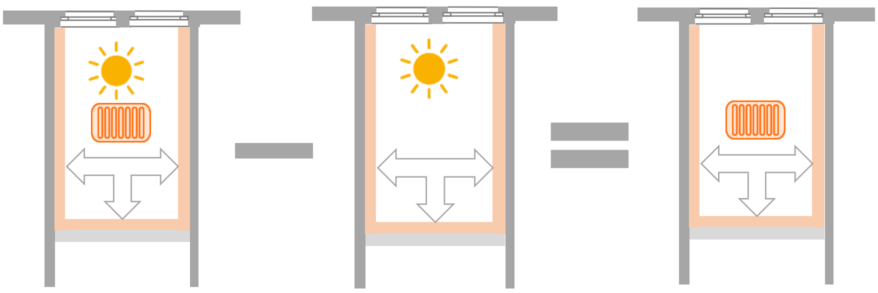

Fig. 6 Analysis process considering the temperature difference between two identical units provided with inside insulation panels: one of the unit is co-heated while both are submitted to identical solar heat gains.

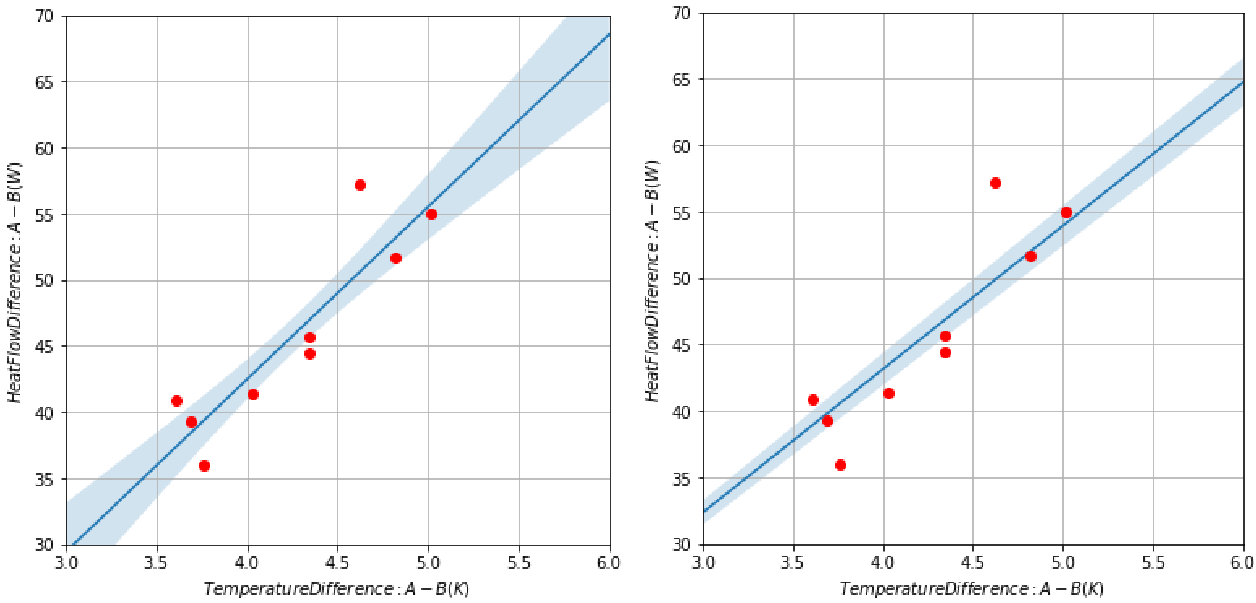

Fig. 7 Correlation between daily mean heat power differences and temperature differences between two identical insulated units, without (left) and with (right) forced intercept.

The façade heat loss coefficient resulting from a linear correlation equals 13.04 W/K with 2.77 W/K standard deviation (fig.7 left). When forcing the intercept, the façade heat loss coefficient equals 10.78 W/K with a standard deviation of 1.66 W/K for the average point (fig.7 right). The intercept can reflect perturbing power in the experiment. The comparison of the two graphs shows that within the uncertainties, the intercept can be assumed to be 0. The difference of the slopes is in the error bars of the left graph on fig. 7.

The HLC obtained by correlation can be used to provide a complete heat balance of each unit, allowing the estimation of the solar heat gains in both of them (fig. 8). The solar heat gains resulting from the heat balances performed separately in both units are well correlated between each other (fig.8, right) and they are well correlated to the solar irradiation measured on a vertical plane parallel to the façade (fig.8, left and middle).

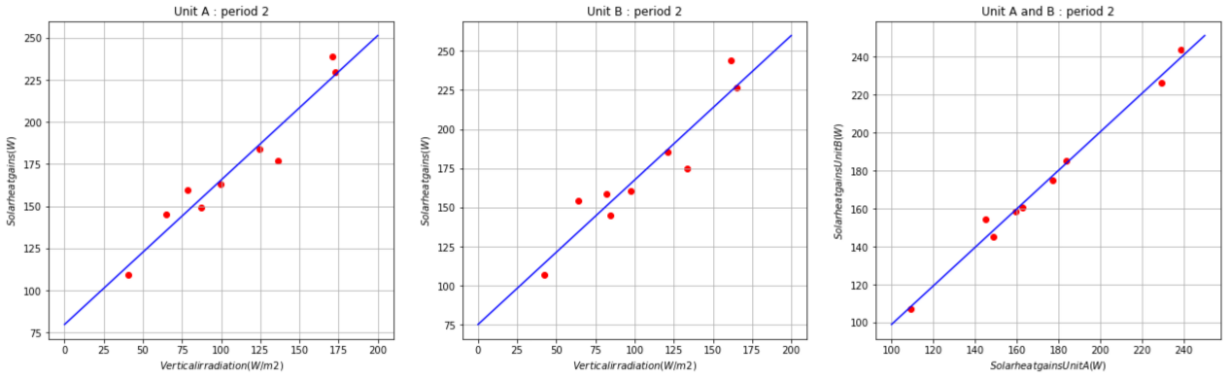

Fig. 8 Correlation between the solar heat gains resulting from the heat balances performed separately in both units, and the solar irradiation measured on a vertical plane parallel to the façade, for insulated units A (left) and B (middle) and correlation between the solar heat gains of both units (right).

3. CONCLUSIONS

The CAM(B)BRIDGE project is implementing a method to control the thermal quality of the building envelope in the construction phase, through a 9 days monitoring period without occupancy. The covering of party walls by insulation panels during the measurements reduces the thermal mass effect and allows internal temperatures to reach higher levels than those observed in the uninsulated units.

An estimation of the heat loss coefficient can be performed by comparing the temperatures and heat flow of two identical units, both submitted to solar heat gains while one of them is co-heated. The HLC obtained by correlation can be used to provide a complete heat balance of each unit, allowing the estimation of the solar heat gains in both of them. The resulting solar heat gains are well correlated to the solar irradiation measured on a vertical plane parallel to the façade, but they still need to be analyzed in order to characterize the shading effect of the screens surrounding the windows. A better understanding of the solar gains 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.

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