EXPERIENCES IN THE AIRTIGHTNESS OF RENOVATED TERTIARY EXEMPLARY BUILDINGS IN THE BRUSSELS CAPITAL REGION

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ABSTRACT

In the “Exemplary Buildings” program of the Brussels Capital Region, building owners and designers are challenged to realise building projects of both high architectural quality and superior environmental performance. After a project competition phase in which the Exemplary Buildings are selected, winning projects are supported by grants and expert guidance throughout further design development and construction. Building envelope airtightness is an important aspect during the follow-up, given its influence on the net energy demand.

This article describes through cases and general trends, the airtightness of renovated non-residential buildings. Several cases studies demonstrate that the resulting airtightness for renovated non-residential buildings, can be as low as the current standards for new-built buildings. The case studies are supported by photographs and technical information, showing the design approach and construction methods which were applied to obtain good airtightness. Airtightness testing will be discussed for the studied cases. This is particularly interesting as intermediate testing has been undertaken in order to enable airtightness improvement works well before final building acceptance. These tests also allow to determine the importance of some of the imperfections before they were mitigated.
General trends can be made by analysing the dataset of renovated tertiary buildings, realised within the Exemplary Buildings program. Keeping in mind that these projects aimed – and were supported – to reach superior environmental performance, the results show that it is possible to obtain excellent airtightness levels when renovating tertiary buildings. Although the dataset for this particular type of buildings is small, overall results of the Exemplary Buildings program indicate a learning effect throughout the years.

The cases and general trends demonstrate that excellent building airtightness can be realised when renovating non-residential buildings, when a coherent design approach, building methods and follow-up during construction are maintained. These results are important, given the necessity of renovating existing building stock in Brussels and the energy performance legislation evolutions, proving feasibility of gradually moving towards airtightness performance requirements similar to passivehouse criteria.

KEYWORDS

Renovation, airtightness, tertiary buildings, practical experiences

1 INTRODUCTION

The Brussels Capital Region started the Exemplary Buildings program in 2007 to illustrate leverage the building and renovation of buildings with high environmental performance. The

aim was to demonstrate that both high architectural quality and superior environmental performance could be reached, even if financial means are limited. After a project competition phase in which the Exemplary Buildings are selected, winning projects are supported by grants and expert guidance throughout further design development and construction. The competitions of 2007, 2008, 2009, 2011, 2012 and 2013 yielded 243 projects of all sizes (Deprez et al, 2012), of a total built surface of over 621.000 m² which were supported by 33 million euros in total, according to the Brussels Environment administration (Brussels Environment, 2014). Over the years, the required levels of performance set forward as an ambition in competition phase were elevated, in order to challenge the market further.
To illustrate the leverage effect of this program, it suffices to mention that in 2007 no building in the Brussels Capital Region answered to the passivehouse criteria, while the Region will have 350.000m² of passivehouse compliant buildings by 2017 thanks to the program.

Part of the program criteria and the passivehouse requirements is the respect of a very high airtightness standard. Next to being key to come to a low energy demand, airtightness also has considerable influence on the thermal and acoustical comfort of the future building owners, by avoiding draught and limiting airborne noise nuisance, which is particularly interesting in an urban environment. However, during technical design and construction works, the aspect of airtightness is an element raising a considerable number of issues. Certainly in the case of renovation, where existing building components with unknown airtightness performance are reused and possibilities in terms of joints and connections between components are limited.

This article describes, by explaining two case studies and an analysis of the exemplary buildings data, the airtightness of renovated tertiary buildings in particular.

2 CASE STUDY 1: EUROPEAN FOUNDATION HOUSE

2.1 Project description

The European Foundation House project (hereafter referred to as EFH), was an existing office building built in 1988, which is renovated and currently occupied by the European Foundation Center (EFC), an international membership association of foundations and corporate funders promoting maecenatism. The 5-story building houses a conference room, meeting rooms, exposition area, office floors (floors 2 to 4) and a cafeteria.

It was decided to maintain the existing façade of natural white stone (see Figure 1) and the existing concrete structure, including the roof structure. Windows and doors were replaced. In order to obtain the targeted energy performance, the existing 6 cm of mineral wool wall cavity insulation were insufficient and internal insulation had to be added. 20cm of insufflated cellulose were added and an interior finishing of a wooden panel and plasterboard was applied. Extensive research was done on thermal bridging and hygrothermal effects, which were reported by Roger France (2013). More details can be found in Table 1 below.

Figure 1: Façade of the EFH building during an airtightness measurement

2.2 Airtightness approach

Airtightness measures taken were taping of joints of panels (Figure 2), use of airtight membranes around the new windows (Figure 3), the implementation of a motorized ventilation grill in the elevator shaft (Figure 4). An intermediate airtightness test has been realised in an upper corner of the building using a temporary wall, which gave the opportunity of testing both exterior wall and roof (Figure 5). These elements are illustrated in the photographs below. As a conclusion of this intermediate and partial testing, it was found that the airtightness membranes around the window frames were able to minimize infiltration, only minor infiltrations in the corner joints were experienced. It was also shown that the bored holes to screw the metal studs to the concrete did not endanger the airtightness. It was difficult to quantitatively predict the airtightness of the building, given the presence of the (not entirely airtight) temporary wall and its temporary joints with walls and roof. In Belgium, airtightness is usually quantitatively characterized as a n_{50} value, which is the measured infiltration rate (in m^3/h) at a pressure difference of 50 Pa between interior and exterior divided by the interior heated volume (in m^3) of the building. As this worst case intermediate testing yielded a n_{50} value of about 1 (h^{-1}) for a building part with several types of walls, corners and joints, it was deemed possible to obtain the same value for the rest of the envelope.

A second and third intermediate testing were done on the entire heated volume of the building (internal volume of about 5750 m^3), which were not yet conclusive as the entrance door was missing, some of the automatic drop seals of the doors appeared to not be adjusted yet, the motorized grills in the elevator shafts was not responding correctly to building controls, etc. For some of the issues, a test was done before and after closing a certain opening by tape or membranes, in order to evaluate the impact on the final airtightness.


Figure 2: Airtightness tapes on the panel joints - Figure 3: Membranes around window frame edges


Figure 4: Motorized grill for ventilation shaft - Figure 5: intermediate testing in a corner of the top floor

2.3 Results and lessons learned

The final figure of the finished building yielded a n_{50} value of 0,91 h^{-1}, which is considerably better than the 1,5 h^{-1} originally put forward as a target by the design team during the Exemplary Building competition stage. Given the availability of intermediate results, the influence of certain elements can be estimated. Firstly, the effect of the motorized grills in the elevator shaft can be estimated. These grills are opened whenever there is a need for ventilation in the elevator shaft (elevator movement, rising temperatures, smoke evacuation), but in general they are closed. This is a considerable reduction of infiltration compared to the standard grills which are opened all the time. During the test, the motorized grills can be closed according to the technical guidelines for airtightness testing within the framework of energy performance legislation (Three Belgian Regions, 2013). During one of the intermediate tests, the grill was tested in opened state. At that moment, the blowerdoor was unable to build up the necessary 50 Pa for official testing, and only about 30 Pa was reached at an maximal airflow through the blowerdoor of about 8000 m^3/h. After closing the grill with a membrane, the measured airflow at 50 Pa was about 6600 m^3/h. Assuming a square root dependency of airflow to pressure difference, the influence of the motorized grills on the n50

value is 0,3 h^{-1}, corresponding to an airflow of 1800 m³/h at 50 Pa. This proves the importance of this kind of device to achieve airtight buildings.
A second influence was the effect of the air-water heat pump. The air intake of this device was combined with the air intake of the ventilation air handling unit. While the latter can be sealed off during testing according to the method A of the European norm (NBN, 2001) which is to be used for official testing in Belgium (Three Belgians Regions, 2013), this is not the case for the former. As a result, this combined air intake had to be left open during measurement, giving rise to infiltration via the metal casing of the heat pump device. By measuring both with opened and closed air intake, this effect could be quantified to an airflow of about 550 m³/h at 50 Pa, corresponding to a difference of about 0,1 h^{-1}on the n_{50} value.
Thirdly, the infiltration airflow through the chinks around doors has been evaluated. By taping all around the doors (in this case, the double entrance door and 3 doors in the basement), it could be established that an airflow of about 700 m³/h at 50 Pa passed through these openings around the – at that time unfinished – doors. This shows the importance of taking the necessary measures (automatic drop seals, flexible draught strips, brushes, filling up voids around door locks) for doors.

Table 1: Key data on the case studies

	European Foundation House (EFH)	**Police office Tritomas**
Building owners	European Foundation House	Zone de police 5342 : Uccle, Watermael-Boitsfort et Auderghem
Architects	GREENARCH architecture + environment sprl	bg&k associati
Engineers	MATRIciel, Delvaux	Crea-tec sprl
Contractors	Valens-Eiffage	CFE
Location	Brussels	Watermael-Boitsfort
Gross building area	2.229 m²	2.327 m²
Start of works	1/12/2012	1/1/2013
Completion of works	9/10/2013	1/1/2014
Energy demand for heating	15 kWh/m²/yr	24 kWh/m²/yr
Energy saving strategy	Interior insulation, window replacement, mechanical ventilation with heat recovery, air-water heat pump, use of radiant ceilings and thermal inertia of the structure	Interior insulation, window replacement, mechanical ventilation with heat recovery, PV panels, geothermal heating and cooling, chilled beams

3 CASE STUDY 2: POLICE OFFICE TRITOMAS

3.1 Project description

Converting a former telephone exchange building into a modern and sustainable police station, was the challenge of the Tritomas project. Given the modernist architecture, which can be considered as part of Brussels architectural partrimony, the choice was made to maximally preserve the building’s exterior, shown in Figure 6. More details of the building are listed in Table 1.

Figure 6: Entrance of the Police Office Tritomas

3.2 Airtightness approach

The technical measures to come to an airtight building were very similar to the first case study, with the use of internal insulation, new windows provided with airtight membranes,… Particular to this project, was the fact that part of the existing building was not touched during the renovation project, moreover, this was in use throughout the construction works by another user (grey zones in Figures 7 and 8). As a consequence, in order to establish good airtightness for the police station, not only external building envelope, but also internal walls and doors had to be airtight. In this project, an intermediate airtightness test was performed on one level (on the first floor, red zone in Figure 8) in order to check the façade concept (internal plasterboard finishing) and its joints. At the end of the project, a measurement was performed on the entire project.

Figure 7: Underground floors (left -2, right -1), coloured zones are part of the renovation project, taken from the test report (Delire et al., 2013)

Figure 8: Building floors (left ground floor, right +1), coloured zones are part of the renovation project, taken from the test report (Delire et al., 2013)

3.3 Results and lessons learned

The result of the intermediate test showed clearly that the applied concepts of façade insulation and window-wall joints for the tested floor were sound, yielding a n_{50} of 0,73 for the tested volume. However, during the testing of the entire building, interaction with the untouched building volume influenced the results. Indeed, during the testing, all doors within the tested volume were opened to enable internal air circulation during the test, and doors to the untouched volume were closed, as shown in Figure 9. As the previous case study showed, doors can influence the airtightness to an important extent. Even when care is taken during selection and installation of the doors – most of the doors were escape exits and had to comply to fire regulations as well – some infiltration losses are inevitable. Given the complex geometrical interface between the tested volume and the untouched volume and the number of doors, the final result of 1,08 h^{-1} is a very good result, compared to the initial target of 1.5 h^{-1}.

Figure 9: Opened and closed internal doors on the first floor, taken from the test report (Delire et al., 2013)

4 GENERAL TRENDS

The dataset of the Exemplary Buildings currently contains information on the measured airtightness of 26 completed tertiary Exemplary Buildings, of which 11 buildings are renovation projects. The entire Exemplary Buildings dataset considers residential buildings as well, however they are not considered in the scope of this article. Also, the design and construction time of tertiary buildings, generally several thousands of square meters, overspans several years, explaining the limited number of completed buildings.

Figure 10 shows the range of building airtightness values measured in the completed buildings, for both new built and renovation projects. It is expected and clearly visible that new built projects have better airtightness, however, our case studies (boxed in the graph) and other renovation projects show that also for renovation projects low n_{50} values are feasible.

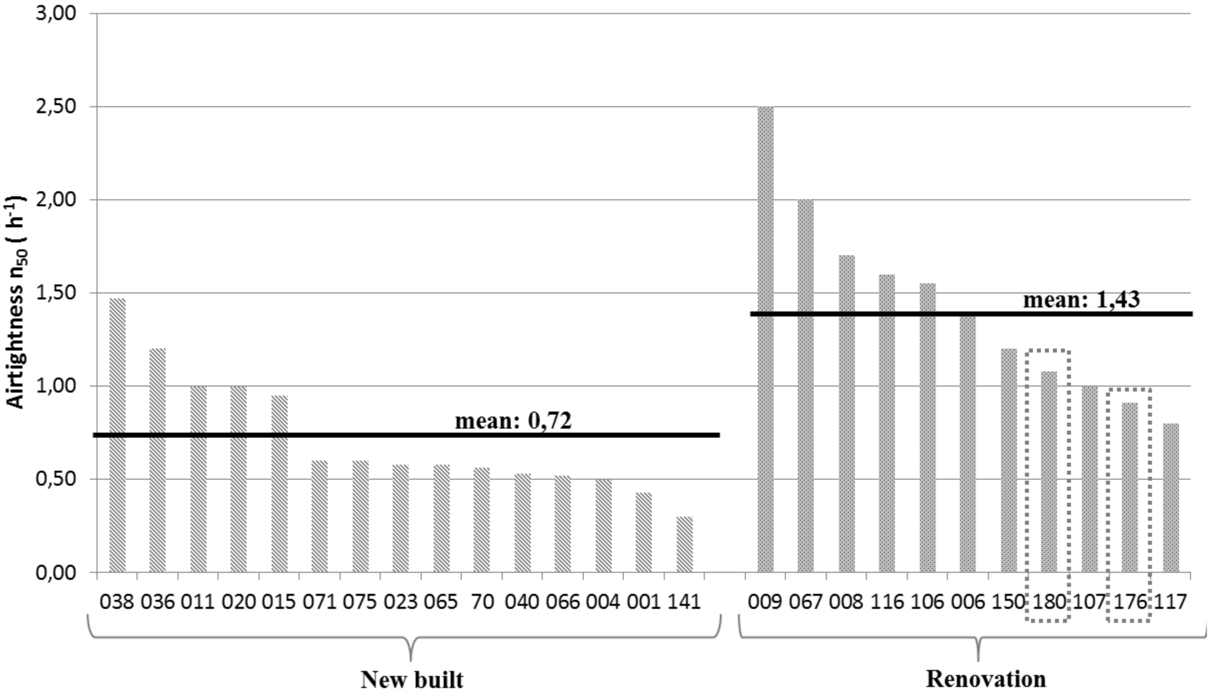

Figure 10: Range of measured building airtightness for new built and renovation in the Exemplary Buildings program. Case studies are indicated in the dotted boxes (case study EFH = number 176, Tritomas = number 180)

Although the dataset for this particular type of buildings is relatively small – too limited to perform full statistical analysis – the overall results of the Exemplary Buildings program indicate a learning effect throughout the years, which is shown in Figure 11. As a complement of information, this effect can also be noticed in the dataset for new built Exemplary projects in Figure 12.

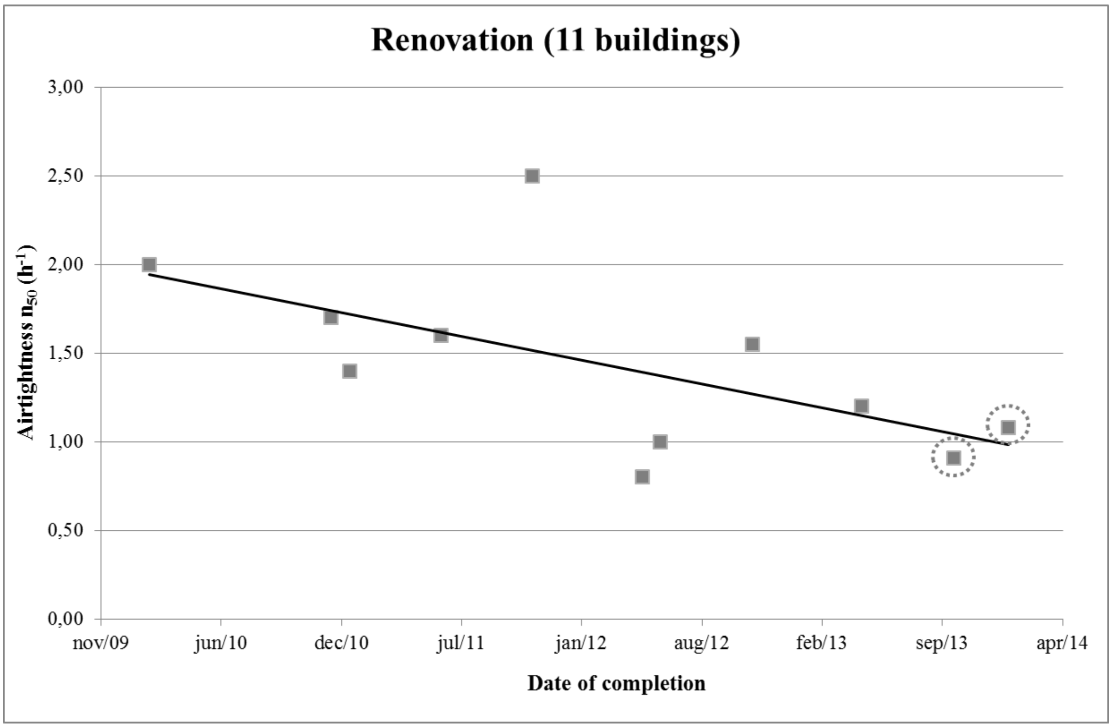

Figure 11: Evolution of airtightness of renovated tertiary buildings in time, dataset of the Exemplary Buildings program

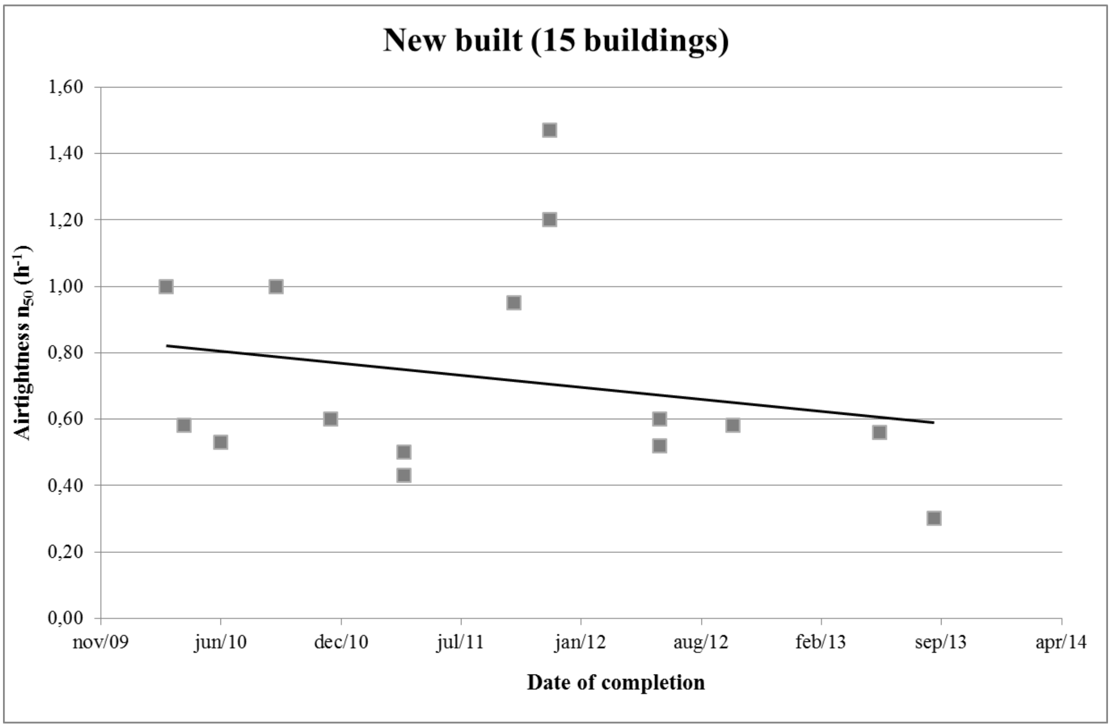

Figure 12: Evolution of airtightness of new built tertiary buildings in time, dataset of the Exemplary Buildings program

5 CONCLUSIONS

The airtightness is an important factor in the energy demand of buildings, but it is a rather challenging aspect of building performance, certainly in the case of renovation projects. The Exemplary Buildings program of the Brussels Capital Region provides – through case studies and the compiled data of realised buildings – a unique insight in the feasibility of high airtightness performance in renovated tertiary buildings. This article proves that – even if a difference remains with new built projects, good to excellent airtightness can be realised in renovated tertiary buildings.

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