Energy efficiency of windows in historic buildings

CONFERENCE PAPER · APRIL 2014

6 AUTHORS, INCLUDING:

Dagmar Exner
Europaeische Akademie Bozen - Accademia …

Elena Lucchi
Europaeische Akademie Bozen - Accademia …

Alexandra Troi
Europaeische Akademie Bozen - Accademia …

Energy efficiency of windows in historic buildings

Dagmar Exner[1], Elena Lucchi[1], Alexandra Troi[1], Franz Freundorfer[2], Mathilde André[3], Waltraud Kofler Engl[4]

[1] Eurac Research – Istituto per le Energie Rinnovabili, Viale Druso, 1, 39100 Bolzano/Bozen – Italy. dagmar.exner@eurac.edu; elena.lucchi@eurac.edu, alexandra.troi@eurac.ed
[2] phc Franz Freundorfer, Martin-Greif-Straße 20, 83080 Oberaudorf – Germany
[3] Menuiserie André Sàrl, 163 route de Chantemerle-les-Blés, 26260 Chavannes – France, mathilde@andre-menuiserie.fr
[4] Direktorin des Amtes für Bau- und Kunstdenkmäler, Armando Diaz Str. 8, 39100 Bolzano/Bozen – Italy, waltraud.kofler@provinz.bz.it

1 Introduction

Windows are inseparable components of the building envelope. They shape the building from architecture point of view – and in a historic building, this aesthetical value is complemented by the value of perhaps still preserved original material. They provide daylight, fresh air and view to the outside, but are energetically speaking also the weak part of the thermal envelope: The thermal transmittance of windows was in the past and remains till today lower than for walls. But windows also let in solar radiation which lightens and heats up the room. Therefore, by optimizing gains and minimizing losses, windows have a huge potential to save energy.

Building efficiency legislation actually has triggered replacement of traditional windows recently, but inappropriate window replacements or upgrades can ruin the historical value of the building and, in addition, cause problems of building physics nature, like condensation, and thermal bridges. In the recent history two main mistakes occurred: the raising of airtightness without raising the air exchange/ventilation at the same time and exchanging of windows without enhance the thermal insulation of the opaque part of the envelope at the same time. This led to a high risk of mould growth because of higher condensation risk (water activity) in combination with less ventilation.

The paper presents a method for improving the energy efficiency of the windows in a historic building, through a progressive approach and targeted intervention that respects the documentary value. After explaining the heritage value of historic windows, glasses and frame and the development of a holistic façade concept, the replacing of an existing window with a high efficient system is discussed. Basis are the experiences from one case study: the Public Weigh House of Bolzano/Italy[1].

[1] Case study of FP7 project 3ENCULT "*Efficient Energy for EU Cultural Heritage*".

2 The heritage value of historic windows and development of a holistic façade concept

By tradition, windows offer lightening, ventilation and protection from outside climate, cold or heat, rain, snow and wind. As a component of the façade, they highly contribute to the architectural expression by giving a vertical and horizontal rhythm to the building. Their design, materials used and technical solutions represent the historical style of the building. The lifetime of the windows is shorter than the one of the building. We can frequently find original windows in buildings from the 19th century, sometimes from the 18th century, but rarely from the 17th century or earlier periods. From conservation's point of view, it is important to preserve as much as possible all the elements, especially for windows dating from the origin of the building. Nevertheless, if the windows do not fulfil their function any more, if anyhow an intervention is needed, the task should be to offer more comfort for the users of the building, save energy and still maintain the original aspect of the windows and thus, of the building.

Historic windows need a retrofit project that takes into account the historic, aesthetic and material values, the state of conservation and the need of comfort for the users. Conservation aspects must be considered at the same level as thermal performance.

Before starting with the enhancement of existing windows, a holistic façade concept for the whole building has to be elaborated in tight collaboration with the conservator. This overall window concept is based on a detailed acquisition and evaluation of every single window during an (interdisciplinary) on-site inspection, describing window typology, state of conservation, construction, materials, installation, surrounding framing (profiled stone frame etc.), type of window sash, glazing, wood joints, fittings and additional equipment such as window shutters etc. From the façade concept emerges which (part of) windows and additional equipment must be retained and which parts can be replaced, as well as the position of the original/new window or respectively the position of an additional new second window layer and how to treat the surrounding framing (reveals, profiled stone frame).

When developing the façade concept, it is crucial to consider not only the thermal performance of the window itself, but also the connection window-wall and the energy balance of the whole building – in order to optimize the heat losses and, most importantly, to assure sufficient internal surface temperatures to avoid condensation and mould growth.

3 Case Study:

The Public Weigh House, a building of Romanesque origins in the historic city centre of Bolzano in Italy, is one of eight case studies that accompanied FP7 project 3ENCULT. At the end of the 16th century, there was a large reconstruction of the building, unifying e.g. the dimensions of window apertures and extending the building on the east side. The window size is therefore typical for baroque era. The major part of the original windows was however replaced by box-type windows in the 1950s/60s – which are not of historic value from conservator's point of view and should be replaced, reproducing the appearance of a historic window. For the development of such a new window the aim was to (i) build a highly energy efficient window with Passive House quality and (ii) a window that answers to the heritage demands of the building.

A first workshop with window developer and producer, building physicist, architect and conservator, helped to understand the aesthetic, visual, formal and functional needs of the new window, before starting with the development of a first concept. It was important to know typical characteristics of local historic windows and relevant recurrent problems in connection with energy refurbishment of protected windows (see figures 1-6). From conservator´s point of view, two aspects of the original appearance of (local) historic windows should be adopted to the new window: (i) the original proportion between glass area and sash bars and window frame and (ii) the optic appearance of original historic glazing.

Figure 1-6: Originally, the wooden frames, impost and sash bars were very fragile and thin, possibly moulded (fig.1-3), while the optic of the typical replacements is much broader (simple application of the IV68 standard, fig.4-6).
Exchanging historic single glazing with double-glazing changes the look to the façade because of different reflection and mirroring, caused by (i) convex or concave deformation of the glass pane through expansion and contraction of gas between the two glass layers, (ii) different surface finish of flat modern float glazing compared with traditional mouth-blown historic glazing and (iii) more regular reflection if subdivisions are not any more glass-dividing (and thus not causing different glass inclination)

In an expert workshop the overall window concept for the whole building was developed: for some rare original windows from the late baroque era, it was decided to possibly enhance them from energetic point of view with an additional second window layer, while the windows from the 1950s should be replaced with new windows, which fit better the historic context.

As there were no drawings from the original historic window available, the new window was based on a "classic" (coupled) window in terms of function, division and proportion, two sashes with two sash bars each. The developed concept separates the demands and functions into two layers: one outer layer for the reproduction of the original historic window and an inner layer for high energy efficiency. In this way, it is possible to obtain the same appearance like the original historic window from outside in terms of frame dimensions, sash bars and mirroring by taking a single glazing, without any negative effect on the energy efficiency. This outer layer takes over the weather tightness. The passive house window with triple glazing is integrated in a second additional inner layer, taking over the airtightness. By rotating the frame cross section 90 degrees and by moving the centre of rotation of the fitting, a smaller frame than the conventional solution was achieved (see figures 7-8). It is positioned in a way that its frame is not visible from the outside. Following to this approach, both box-type and a coupled window are executable (see figures 8-9). Additionally, it allows also preserving the original old window and just adding the second energy efficient layer (on the inside or also on the outside).

On the installed prototype of the coupled window version the conservator evaluated if heritage demands have been fulfilled: the appearance of the outer single glazing and the optic of the inner triple glazing, the proportions, subdivision and frame thickness and the evaluation of the concept of “division of functions” as well as colour and profiling. Based on this feedback the prototype was developed further. Since in the meanwhile a building historian had discovered traces of cut out imposts (in some rare cases where the outer sashes the of box-type window from the 1950s/60s where installed in an original baroque frame), the new prototype was also built with a horizontal impost and four window sashes (2 above, 2 below). As model served the still existing window with impost in the jutty. The use of the very thin triple glazing (2/8/2/8/2), with the thickness of a double glazing, made it possible that the frame proportion became even more fragile and the optic from inside becomes very similar to a double glazing (see figure 11).

The application of the concept and the execution of the window prototype profited from the flexibility, experience and know-how of the small traditional window producer, which is able to tailor his facilities to the production of this individual adapted windows.

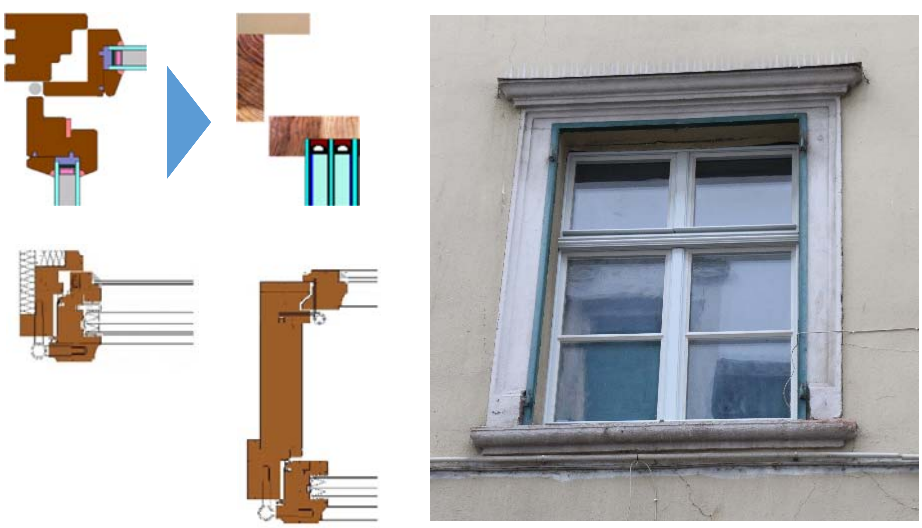

Figure 7-11: rotation of the frame cross section by 90 degrees (fig. 7-8) to achieve a smaller frame; separation of functions into two layers: “historic” window outside, integration of passive house window inside (fig. 9-10), last prototype installed in the Weigh House (fig. 11).

With regard to the window-wall connection, since in the major part of the case study, no application of internal insulation is possible, the junction was optimised by studying the existing reveal on-site and inserting all around the window an insulation layer of 4-6 cm. This helped two improve the psi-values and thereby to rise the surface temperatures in the critical points to required values (see figures 12-13).

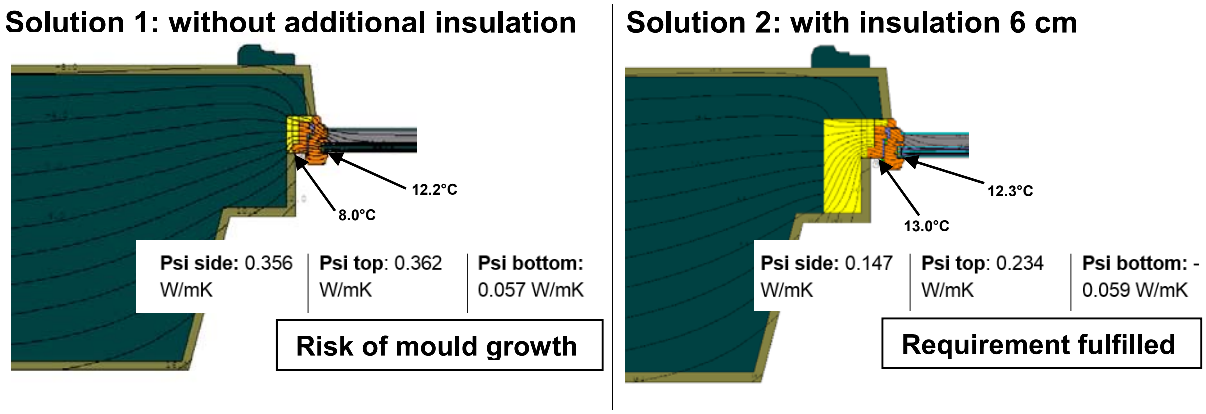

Figure 12-13: comparison of two window connections – with and without additional insulation

The entire transmission heat losses caused by the original windows are 31.100 kWh/a. With the installation of the developed window (with triple glazing) a reduction of 21.000 kWh/a can be achieved. Taking into account the window energy balance (losses minus gains) the net losses can be reduced by 70% (double glazing vs. original window) or respectively 80% (triple glazing). Looking at the total energy balance of the whole building with 14% of window area and walls in natural stones, the exchange of windows can reduce the demand by up to 20%: 10% due to thermal performance increase, 10% due to airtightness improvement (need for indoor air quality considered, without heat recovery).

4 Flexibility of the developed smartwin window concept

The flexibility of the developed window system allows the integration of an original historic window. In case of the three baroque windows in the bay, it is important to maintain the interior view; the additional layer should be added therefore on the outside. For these windows the following solution was developed: removing the existing wooden frame outside, which served for the fixing of the window shutters. Instead of those, provide a second window layer, which takes over the energy efficient function (concept of the composite window prototype “the other way round”). The outer wing can be opened to the outside; it can be executed without the horizontal impost (only one sash). For the other remaining three original windows, instead it was decided to apply the second layer on the inside.

5 Compatible energy retrofit of historic buildings

An adequate enhancement of windows in historic building requires a tight collaboration between architect, window developer and producer and conservator from a very early planning stage on. The multidisciplinary team should follow the following approach:

Step	Measure	Content/scope
1.	**On-site inspection (with conservator)**	Documentation of every single existing window, evaluation of the heritage value of the window and its components, definition of an overall façade/window concept

2.	**Multidisciplinary workshop**	Definition of aesthetic, visual, formal and functional needs of the enhanced window. Definition of window details such as proportions, material, profiling and finish with the help of detail drawings.
3.	**Calculation of window connection**	Study and optimization of window/wall joint, both for minimization of heat losses at the connection and assurance of minimum internal surface temperatures and a minimum air exchange to avoid condensation and mould growth
4.	**Calculation of building energy balance**	Building energy balance: evaluation of different window technologies (e.g. different glazing solutions), taking into account reachable airtightness level and installation variants (window/wall joint) on building level.
5.	**On-site inspection (with conservator)/ multidisciplinary workshop**	Building and installing of first prototype – evaluation of conservator, possibly improvement, further adaptation

6 Conclusions

A significant energetic enhancement of historic windows is possible, while maintaining the historic value of the building and the window, thanks to the developed smartwin window concept. The flexible system is adaptable to the single individual case: Be it in case of improvement of an existing window by inserting of a new window layer or be it in case of the exchange of an existing window. Prerequisites are however: (i) the tight collaboration of planer, window developer and conservator from an early planning stage on; that (ii) with a sensitive approach adapt the developed window concept to the individual case and take (iii) into account not only the window performance, but also the impact of the installation to the whole building. Furthermore, there is the need to find window manufactures that have the necessary handicraft skills and facilities to produce smartwin historic windows.

Acknowledgements

This work has been funded by the European Union, through the research projects “3ENCULT: *Efficient Energy for EU Cultural Heritage*” (Seventh Framework Programme, grant agreement n° 260162).

References

Freundorfer, F.: Passivhausfenster der Energieeffizienzklasse A in denkmalgeschützten Gebäuden. Passt das zusammen?, Hannover 2012

André M., Freundorfer F.: D 5.2 New heritage-compatible window, 3Encult, January 2014

Exner D.: Minutes of 3Encult Workshop on Windows, 3Encult, August 2011

Franzen, C. et al: D 7.6 Conservation compatibility, 3Encult, November 2013