The eyes of the city: Historic casement windows as a threatened asset of cultural heritage.

Improvement of casement windows with vacuum glazing.

Ulrich PONT, TU Wien, Department of Building Physics and Building Ecology, Austria
Peter SCHOBER, Holzforschung Austria / Austrian Forest Products Research Society, Austria
Magdalena WÖLZL, TU Wien, Department of Building Physics and Building Ecology, Austria
Matthias SCHUSS, TU Wien, Department of Building Physics and Building Ecology, Austria
Jakob HABERL, Holzforschung Austria / Austrian Forest Products Research Society, Austria
Karin HAUER, Holzforschung Austria / Austrian Forest Products Research Society, Austria
Ardeshir MAHDAVI, TU Wien, Department of Building Physics and Building Ecology, Austria

Keywords: *Casement Windows —Thermal Retrofit — Vacuum Glazing Products — built environment — thermal improvement.*

CHNT Reference: Pont, U., Schober P., Wölzl, M., Schuss, M., Haberl, J., K. Hauer (2021). 'The eyes of the city: Historic casement windows as a threatened assed of cultural heritage: Issues, Questions, Research and potential Solutions', in CHNT – ICOMOS Editorial board. *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies.* Heidelberg: Propylaeum.

Introduction

Traditional casement windows are considered not only as aesthetically sophisticated window constructions (see Figure 1a), but also as those window construction that have been subjected to century-long optimization processes. Rough estimates state that there is a large number of these windows still to be found in the building stock of European cities, e.g. Vienna. However, the number is in constant decline, as casement windows often are considered to be expensive in maintenance and dissatisfactory in their thermal performance and fulfilment of current comfort desires of building occupants, and thus are often demolished and replaced by new windows. Moreover, many building retrofit subsidy projects do not consider the restoration of windows as a feasible measure and only subsides window exchange. Needless to say, the replacement of casement windows with modern-day single layer multi-pane windows in historic facades is often a fundamental distortion in the corresponding façade appearance and thus a threat to the built cultural heritage of cities. The Austrian monuments office thus states in their guideline onto energy performance of building stock that a replacement of exiting historic window constructions is regularly a no-go in building conservation (BDA 2011). However, the necessity to severely reduce building-related energy consumption requires also technologies for improvement of existing buildings. Windows are considered one of the building construction elements that are "weak spots" in the envelope, and thus is their improvement considered a leverage improvement. As such, new approaches are required that encompass both the improvement of the thermal performance of the windows and ensure the upkeep of the appearance of buildings and preservation of the historic casement windows. The research unit of Building Physics and Building Ecology of the TU Wien, Vienna Austria, started together with the Austrian

Forest Products Research Society (Holzforschung Austria) in 2014 R&D efforts toward implementation of vacuum glass in existing window constructions with the goal of significantly increased thermal performance at little to no aesthetical impact onto the windows. The implementation of vacuum glass in existing window constructions brings up a set of questions, such as thermal performance improvement of the window, thermal bridge effects in the glass/frame/Wall joints, and constructive integration possibilities. A project started in 2019 (VAMOS) focussed onto the construction implementation of vacuum glass in demonstration windows, which was accompanied by comprehensive simulation

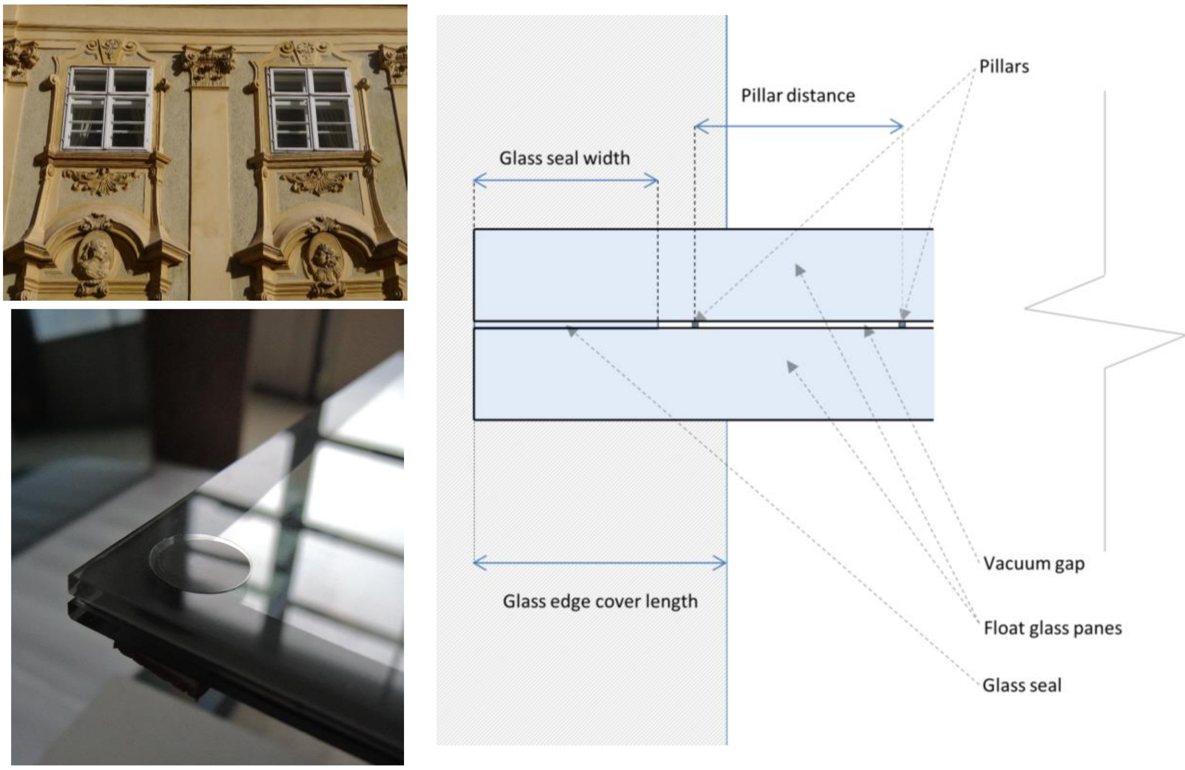

Fig 1: a (left top): Historically relevant casement windows in a decorated façade in Vienna (Photo by P. Schober); b (left bottom): A vacuum glazing product including tight edge seal and evacuation opening (Phot by P. Schober); c (right): Schematics of vacuum glazing product's terminology (Ilustration by U.Pont/M.Wölzl)

Vacuum glass

Regularly, the term vacuum glass describes a transparent building component that encompasses two parallel glass panes with a thickness of 3 to 4 mm with an interstitial space of less than a millimetre. Moreover, an air/vacuum-tight egde seal runs around the perimeter of the interstitial space. A grid of so called distance pillars is positioned within the interstitial space as well, which is also equipped with an evacuation opening that is sealed after the evacuation. The pillar's function is to maintain the parallelism of the glass panes once the interstitial space got evacuated. Such glass products widely eliminate the heat transfer mechanisms of conduction and convection, which results in very low thermal transmittance characteristics, especially in comparison with float glasses of similar system thickness. The U_g-value (thermal transmittance) of typical vacuum glass products ranges between 0.4 and 0.7 $W.m^{-2}.K^{-1}$. From a perspective of thermal performance, the thermal bridge along the edge seal can be considered as weakest spot. Figure 1b shows a vacuum glass product while Figure 1c illustrates the typical constituents of a vacuum glass in a schematic drawing.

Performance determination of vacuum-glass equipped casement windows

In the research projects VIG-SYS-RENO (2014-2015, see Pont et al. 2018) and VAMOS (2019-2021, see Pont et al. 2021) different efforts have been conducted towards the integration of vacuum glass in casement windows. The former study focussed on the confirmative testing of vacuum glazing performance values (as provided by the South-East Asian producers) via lab testing (durability, thermal conductivity, acoustical performance) and the principle implementation of such glass products in existing window constructions as potential replacement for float glass. The latter project deepened the construction understanding of vacuum glass implementation via the help of small scale window carpenting enterprises. Thereby numeric thermal bridge simulation was deployed to predetermine the thermal performance of such windows (Temperatures and Dew-Points at critical points of the construction). The simulation offered the inexpensive exploration of performance consequences by different design and construction decisions. Subsequently, casement windows of six different test sites in Austria were equipped with vacuum glass and extensive monitoring equipment was installed at the specific windows. For about 9 months, including a cold season, each site was monitored. Thereby at least three windows at each test site were monitored: One window without any modifications (original state), one window with vacuum glass integrated in the outer glass layer and one window with the vacuum glass utilized for the inner glass layer. The different sites not only featured different microclimatic conditions and building usages, but also represented different types of casement windows. The monitoring was conducted via tailored sensors and collected data was in real time relayed via WiFi to the World Wide Web and then stored in a specifically adapted monitoring software solution (See Schuss et al. 2021). Moreover, building occupants were asked to document if specific events such as condensation on the glass surfaces could be noted.

In five of six demonstration sites the vacuum glass equipped windows showed not only a significant improvement of the window U-values (the U_W-value dropped from values between 2.0 and 2.5 $W.m^{-2}.K^{-1}$ to values around 1 $W.m^{-2}.K^{-1}$), but did not show any traces of condensate. The control windows (original state) showed significantly higher U_W-values, and – at some occasions – also showed traces of condensation. The question, if the implementation of vacuum glass can be recommended for the inner or the outer layer of the window cannot be answered in general, as this is highly dependent from the type of casement window and the position of the glass layers in relation to the wall opening. Moreover, the perimeter material around the window niche influences the suitable position (in case of highly conductive wall materials the application of the vacuum glass on the inside is favourable). Furthermore, the implementation potential of window seals and/or the air tightness of the overall construction is of high importance. Needless to say, a specific detailed planning is required for any retrofit planning encompassing vacuum glass windows. However, it could be proven both in virtual (imulation) and real experiments (lab and on-site tests and monitoring) that vacuum glass could offer a feasible way to improve casement windows' energy performance without severe change of the windows and thus the façade's appearance. As such, we believe that this improvement could be a feasible contribution to both the protection of built cultural heritage and reduction of building related energy consumption.

Funding

The research efforts described in this contribution have been generously funded by the Austrian Research Promotion agency (FFG; VIG-SYS-RENO 2014-2015, Project no. 845225, and VAMOS 2019 – 2021, Project no. 878272).

Conflict of Interests Disclosure

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Pont, Schober
Data curation: Schuss, Wölzl, Pont, Schober
Formal Analysis: Pont, Schober, Schuss, Wölzl, Hauer
Funding acquisition: Pont, Schober, Wölzl
Methodology: Schober, Pont, Wölzl, Schuss, Haberl, Hauer
Project Administration: Pont, Wölzl, Schober
Validation: All authors
Visualization: Schober, Wölzl, Pont
Writing – original draft: Pont
Writing – review & editing: Pont

References

BDA (2011): Richtlinie Energieeffizienz Am Baudenkmal, Austrian Monuments Office, 2011, available via: https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinie_Energieeffizienz_am_Baudenkmal.pdf

Pont, U., Heiduk, E., Schober, P., Romirer, H., Dolezal, F., Proskurnina, O., Schuss, M., Sustr, C., Hohenstein, H., Mahdavi, A. (2018): Sondierung von Fenstersystemen mit innovativen Gläsern, speziell Vakuum-Isoliergläsern, zur Gebäudesanierung; Schriftenreihe 33/2018, BMVIT / Federal Ministry of Traffic, Innovation, and Technology; available via https://nachhaltigwirtschaften.at/resources/sdz_pdf/berichte/schriftenreihe-2018-33-vigsysreno.pdf

Pont, U., Schober, P., Wölzl, M., Schuss, M., Hauer, K., Haberl J., Mahdavi, A. (2021): Endbericht VAMOS; to be published / BMK – Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, Republic of Austria.

Schuss, M., Pont, U., Wölzl, M., Schober, P., Mahdavi A. (2021). In-situ performance evaluation of historic box-type windows with vacuum glazing. Presented at the IBPC 2021, August 2021, Copenhagen; Proceedings to be published.