Energy and Buildings 126 (2016) 51–69

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

# Simulation aided optimization of a historic window's refurbishment

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ARTICLE INFO

*Article history:*
Received 30 November 2015
Received in revised form 31 March 2016
Accepted 3 May 2016
Available online 6 May 2016

*Keywords:*
Historical box type window
Window refurbishment
Fenestration heat balance
Shading control
numerical modeling
energy efficiency

ABSTRACT

A recurring problem in retrofitting historic windows is that most traditional means of improving their energy efficiency, e.g. the use of IG units, is often unavailable due to structural and esthetic concerns. Through a refurbishment project of traditional Central-European box windows we aim to investigate the possibility of using less intrusive methods to improve the windows' heat balance with comparable results. Many different approaches to calculating the energy balance of windows in historic buildings are reviewed and various modelling assumptions and algorithms analyzed to highlight the depth of modelling needed for fenestration heat balance calculation in a historic context. We introduce our new research program for the task: EPICAC-BE, a MATLAB based dynamic energy simulation software. After a validation with the BESTEST suite it is used to compare different retrofit options for a prototype window with and without controlled shading devices. Results indicate the use of double glazing units is not always required or the most favorable. Utilizing the dynamic window concept by combining higher U value with higher solar transmittance with automatic interpane shading can achieve better overall results. Simulations should have a key role as they can lead to designs better satisfying both energy saving and conservational requirements.



## 1. Introduction

In the last few decades the preservation and restoration of historic windows in central-Europe and elsewhere was the subject of many studies. The most important structural details of 19th century windows, their common failures and the techniques to mend them are well documented, amongst others in books such as [1–3] or [4]. However, though window restoration and refurbishment is mostly the area of specialized practitioners even they base their work largely on rules of thumb and simple design guidelines (such as “HO.09 Runderneuerung von Kastenfenstern aus Holz” [5] in Germany) that can only ever provide generalized solutions for the less demanding cases. Furthermore, the thermal improvement of historic windows, though definitely part of most of the mentioned publications, is usually not treated in a systematic fashion. The majority of works only present one or two possible solutions which leaves little room for a possible thermal optimization.

In early 2014, we received the commission to conduct a decision support study analyzing the possibilities of, and then prepare the plans for, the structural and thermal refurbishment of the windows of a very prestigious building: the Palace of the Hungarian Academy of Sciences (Magyar Tudományos Akadémia, henceforth: MTA). The structure, located in the heart of the Hungarian capital Budapest, was designed in the Neo-Renaissance style of contemporary German palaces by the architect Friedrich August Stüler, and built between 1862 and 1865 [6]. The refurbishment of such a national monument is a delicate task, not only because its architectural, historical and societal significance, but also due to its use of noble materials, exquisite detailing and special constructional solutions. The appearance of the windows, and if at all possible the actual window stock had to be preserved.

In the MTA building there are more than 200 windows of 23 different size, shape and opening type in rooms of even more varying size and usage. No single solution can give nearly optimal results for all of them, therefore relying on only the existing simplistic guidelines for the design was clearly inadequate. Instead, a stepwise approach was adapted with the following stages: 1) a detailed architectural survey of all fenestration, 2) cataloging of the structural damages and deficiencies aided with all the diagnostic tools that were available to us (e.g. Blower Door measurements and IR thermography), 3) a survey of occupants' complaints and wishes regarding thermal comfort 4) the formulation of a well founded refurbishment concept to address the typical structural problems and to demonstrate an optimized thermal solution for a typical

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http://dx.doi.org/10.1016/j.enbuild.2016.05.005
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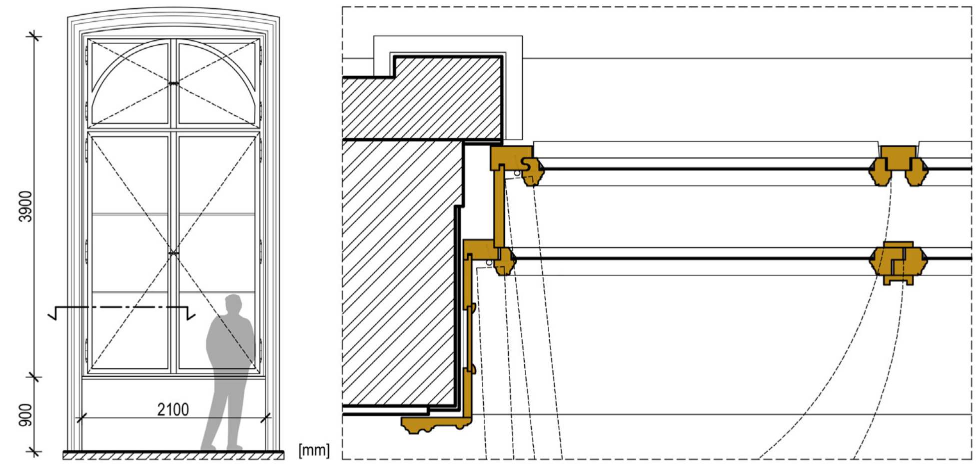


**Fig. 1.** The prototype window of the MTA building, internal view with dimensions (left) and horizontal section (right).

single window based on the comparative numerical simulation of a multitude of refurbishment methods, 5) the well documented restoration of this prototype window under constant supervision, and 6) the detailed evaluation of the finished prototype by a long-time monitoring. The final decision for the rest of the windows will be based on the experiences with the prototype and the use of the design and calculation method developed for its creation. For the prototype refurbishment we chose a typical office room with a single window located at the intermediate floor of the building and oriented towards the west and the embankment of the Danube river (henceforth: the reference room and the prototype window).

The selected window, like the majority of the windows in the building, is a so called box-window (or Kastenfenster in German), a typical construction for the region in the building period. These are double-skin windows with two layers of wooden side hung sashes, each with a single pane of glass. All of the sashes are inward-opening with the outer frame and sashes having a slightly smaller size to make this possible (see Fig. 1). An around 20 cm deep casing connects the exterior and interior frames forming an air layer between the two providing additional thermal resistance. The peculiarity of the building's windows is their enormous size, the resulting extreme slenderness of the frame and sash profiles and the use of thin cast iron glazing dividers in an otherwise completely wooden construction. Though these all make the huge windows very elegant, they also limit the possibilities for structural changes to increase their functionality and decrease their heat losses. The 'toolbox' to improve the thermal performance of old but valuable windows that are to be preserved usually contains three main items:

- the increase of airtightness through a general renovation and the installation of new rubber gaskets to reduce in- and exfiltration, with possible additional modification to the operating hardware to improve the seal
- the modification of the glazing layers to improve its solar-optical and thermal properties, most often with the use of applied films on existing glazing, single-pane hard coated low-e glass, or multi-pane insulating glass (IG) units
- the use of exterior, interpane or interior shading devices or other attachments with the same purpose

The use of IG units is by far the most favored option of the majority of contemporary practitioners, but usually is limited by the fact that even double pane glass can be too heavy and too thick to fit into the small sized sashes and glazing rebates of traditional windows. This problem is often solved by replacing one layer of sashes with larger ones having the necessary size and strength, or the use of extra thin and light insulating glass units made specially to fit into the existing construction (with the compromise of sub-optimal cavity size and reduced mechanical strength due to the small glazing thickness). Due to the building's status as a first class national monument and its architectural quality any noticeable increase of the sash profiles or the complete elimination of the cast iron dividers, in the interest of the use of normal thick and heavy IG units, was ruled out completely. The use of thin double glazing would require the transformation of the iron dividers to a 'fake' grill glued on the internal surface of the glazing. This modification would be irreversible and of a lower architectural quality, but necessary to minimize the thermal bridges that would severely reduce the usefulness of any double glazing. On the other hand, using only single glazing, whilst allows to keep the iron dividers, limits the choice in available coatings. Hard-coatings suitable for single glazing applications are much less used today and their performance is not so well optimized as that of soft-coatings only applicable in the inside of IG units.

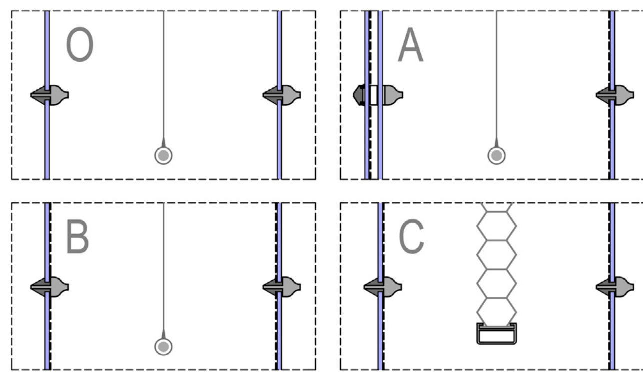


**Fig. 2.** Schematic view of the different glazing system options (scenarios) drawn though the cast iron glazing dividers.

Following the process described earlier the following main scenarios were devised for the refurbishment of the prototype window (listing only the points relevant to the windows' thermal performance) (see also Fig. 2):

- Scenario A—named 'thermally optimal':

I general refurbishment of the frame and sashes, installation of rubber gaskets in the internal opening to increase airtightness,