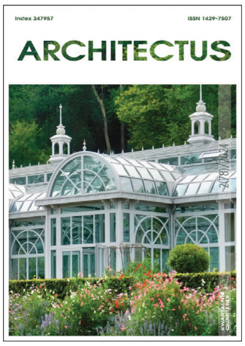

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Historical windows and their impact on the energy balance of the building

Abstract

With the increasing emphasis on making existing buildings energy efficient, window replacement in historic buildings has become an important and controversial topic. In the presented work, contemporary trends of European and global scope regarding the replacement of historic woodwork with new woodwork are presented. Based on an analysis of the literature on the subject, the issues of maintenance, repair and thermal modernization of old windows are discussed to try to determine how and to what extent the replacement not only adversely affects the aesthetics of the building, but also the economic aspect and the final energy balance of the building. The purpose of the article is to show the historic window as an architectural detail that is worth preserving at all costs during the renovation of the building, upgrading it to meet modern energy requirements. Attention is also given to the issue of sustainability and respect for the architectural heritage of the building's surroundings.

Key words: historic windows, renovation, sustainability, energy balance

Introduction

The loss of original, antique woodwork from historic buildings is one of the main threats to our heritage. Traditional window frames and glazing are important to historic areas, and their value goes far beyond aesthetics.

Originally, the windows were openings in the wall covered with skins or fabrics, which, with the passage of time, were replaced by wooden shutters, set on hinges. Shutters can be considered the first protections from weather conditions in history. Over time, the function of the window became not only to allow light to enter the interior, but to protect it from the elements. Window openings also had a decorative function, enriching the architectural form of the building façade. The article pays special attention to wooden windows, among which the following types can be distinguished: loom, frame, box, composite, single-frame [1, pp. 7–9].

By building tangible connections to the past, windows contribute to a unique sense of place, strengthening the connection between communities and their heritage. They are a testament to craftsmanship as well as artisanship and can be important artifacts in their own right, often made with great care and ingenuity, using materials of higher quality than those generally available nowadays (Fig. 1). The distinctive look of historic handmade glass is not easily imitated by modern glazing. Original historic window woodwork also represents an environmental value, as the maintenance and restoration of existing windows reduces the need for new production and promotes sustainability.

Windows are particularly sensitive building elements because they are relatively easy to replace or change. Such work often has a profound aesthetic and compositional impact not only on the building itself, but also on the appearance of the street and neighbourhood. The depth and thickness of the frames and sills, the width and visual weight of the sash elements, the materials, colour and pattern of the light reflecting off the glass – all complement and emphasize the architectural style, texture and age of the building. Modern counterparts tend to have wider mullions that provide less light to the interior (Fig. 2). Much of this character is lost when windows are replaced with their modern counterparts, which lack these features. There are simple ways to repair and upgrade window frames that are fea-

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Fig. 1. Cracow, Poselska 7, antique window joinery:
a) interior view, b) view of exterior façade (photo by D. Strzałka-Rogal)

Il. 1. Kraków, ul. Poselska 7, zabytkowa stolarka okienna:
a) widok od wnętrza, b) widok elewacji zewnętrznej (fot. D. Strzałka-Rogal)

sible for the building owner or craftsman, and that benefit the building's energy balance [2].

The topic addressed in the article remains controversial for many researchers, as arguments about historic values and energy efficiency collide. In the available literature on the subject one can find items presenting solid arguments for both preservation and replacement of historic windows. In her paper, the author focused on analysing a group of research papers in which historical value is put before energy efficiency, citing, among others, the research collected in the article *Windows in historic buildings: sustainable, repairable* Susan D. Turner [2], the methods described in the guide *Traditional windows. Their care, repair and upgrading* by David Pickles et al. [3], research in *What replacement windows can't replace: the real cost of removing historic windows* by Walter Sedovic and Jill Gotthelf [4] and *Repair or replace* by Craig Sims and Andrew Powter [5]. The purpose of this article is to show the historic window as an architectural detail that affects the energy balance of a building – an element that is worth preserving at all costs during a building renovation.

Window replacement

Although old windows are often seen as the elements responsible for heat loss in a building, preserving historic woodwork is crucial to maintaining the integrity and authenticity of buildings.

An economic analysis of the life cycle of a single window has shown that replacing historic windows to reduce heating costs is largely a myth and remains the result of misinformation disseminated by manufacturers[1] [2]. It turns out […] *that high-quality equivalent replacements cost up to three times more than restoring a historic window* [4, p. 29].

Windows with vinyl or aluminium cladding do not require cyclic painting, as is the case with wood, but they scratch and fade, factory seals fail, and joints can separate [4]. These forms of deterioration cannot be stopped by maintenance. In modern windows, serious irreparable damage to the sealing joints occurs within 10–25 years [5]. Currently, most seals are only warranted for 8 to 10 years. Regardless of its resemblance to the architectural original, a replica will also never convey the nuances of the original (Fig. 2) [6].

Renovation of historic windows

A successful historic window restoration project requires a clear understanding of the existing condition and the owner's expectations for the maintenance and life of the windows [7]. If possible, a comprehensive study of

[1] Sims and Powter cite a belief dating back to the energy crisis of the 1970s. According to them, this was a view repeated by all Canadian government agencies concerned with helping homeowners save energy [5].

Fig. 2. Cracow, Poselska 7, antique window joinery:
a) interior view, b) construction of a casement window (photo by D. Strzałka-Rogal)

Il. 2. Kraków, ul. Poselska 7, zabytkowa stolarka okienna:
a) widok od wnętrza, b) konstrukcja okna skrzynkowego (fot. D. Strzałka-Rogal)

existing windows can more accurately tailor a restoration approach that achieves the desired effect [8]. Based on this experience, it is estimated that at least 95% of original windows can be restored – there are countless examples of windows that are 250 years old with a remaining useful life of 100 years with proper restoration and maintenance [6].

Assessing the significance of the window or windows and their contribution to the overall character of the building is the first step in deciding on the appropriate course of action [7]. The preservation of a historic original façade is an irreplaceable heritage resource that should be left and repaired whenever possible [8]. The significance of a historic building, both as a whole and in terms of its component parts, can be assessed by considering its heritage value [9]. Historic window systems are typically built with great attention to detail (such as weather protection) and with good quality materials (such as heavy-duty wood) [2]. Problems associated with the passage of time – peeling paint, cracked glass and missing putty – can look unsightly, but they are easily repaired (Fig. 3) [10].

Some materials (such as PVC) used in replacement windows are inherently unsuitable for maintenance. Once the material degrades, it will need to be replaced. One of the biggest advantages of historic windows is the quality of the wood from which they are constructed [11]. Historic windows use wood that has a denser, more natural grain structure than what is available today. In addition, in the past, more attention was paid to milling methods, such as quarter sawing or radius sawing. The resulting window is characterized by greater stability than its modern counterpart.

In many cases, traditional windows are slated for replacement due to their poor thermal properties. Research shows that thermal performance can also be improved through relatively inexpensive methods such as the use of blinds, shades and curtains. Further increases in performance are possible with the introduction of methods such as secondary glazing, which allows the historic character of the window to be preserved [12].

The results of a study cited by Søren Vadstrup [11], prove that existing old/original wood single-glazed windows with mastic sealed frames can be energy retrofitted with interior double-glazed windows or frames coupled with energy-efficient glazing, saving 30–50% more heat than equivalent new wood, plastic, aluminium or wood-aluminium double-glazed windows or the latest low-energy thermopanes[2] [11]. Even if an energy window has very low heat loss through the centre of the glass (centre *U*-factor), the energy loss calculated for the entire window (including edge losses, for example) will be higher than for a similar old putty window with energy glass inside. If all energy-efficient glazing is used in the interior glazing, the differ-

[2] A material composed of two plates of flat window glass, glued together exactly at the edges, leaving a gap of about 6 mm, which is provided by strips of glass inserted between the plates; slit glass, hermetic glass.

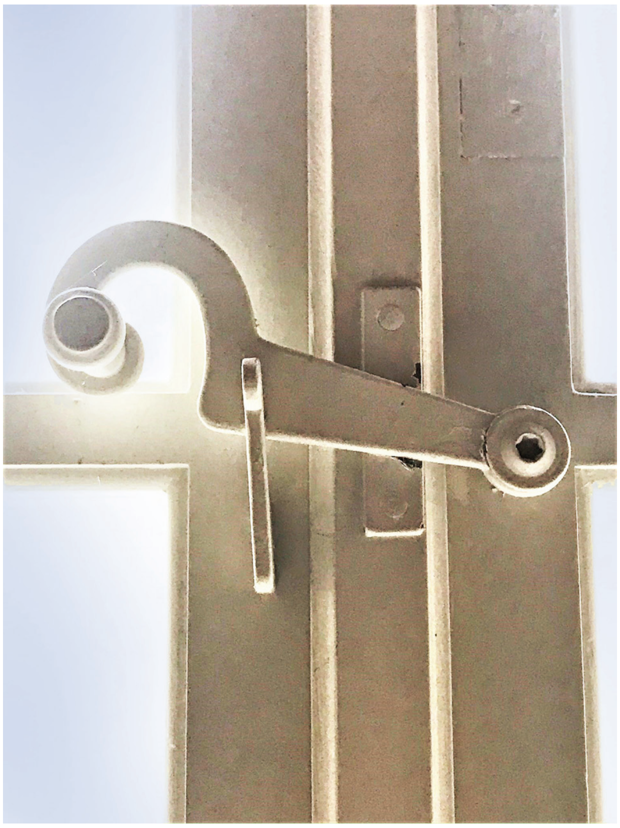

Fig. 3. Cracow, Poselska 7, a deadbolt after renovation (photo by D. Strzałka-Rogal)

Il. 3. Kraków, ul. Poselska 7, zasuwka po renowacji (fot. D. Strzałka-Rogal)

ence is even greater in favour of the old windows [11][3]. This solution is also the best in terms of traffic noise attenuation, the risk of external condensation on the glazing, and the several-hundred-year lifespan of the entire window. In addition, in terms of environmental performance and CO_2 balance, the energy-efficient old window also achieves the best values. In a similar study, it was also documented that ongoing maintenance for 30 years is also significantly cheaper for old energy-efficient wood windows if they are maintained according to regulations with linseed oil paint, compared to similar new thermal windows made of wood, plastic, aluminium or wood-aluminium.

[3] In December 1999. The Raadvad Centre was awarded a research project under the Danish Energy Agency's Project Window (J.nr. 75661/99-0006) on improving the energy performance of existing windows in older buildings. The Raadvad Centre, together with various other collaborators, also conducted work on life cycles, life cycle analyses, sound and light quality measurements for old and new windows. The result of the research clearly indicates that new windows with insulating glass or energy glazing are not the right choice in terms of energy or heating management in older homes, compared to renovation of old windows complemented by replacement windows with energy glazing or energy-saving glass. This means that in buildings older than 60–70 years, old wooden windows should be preserved and repaired, and energy-efficient glazing or energy-efficient glazing should be installed inside them as coupled frames or front windows. This improves heating efficiency and overall economy, while preserving the architecture of the building [11].

Energy balance

When considering the impact of older windows on the energy balance, it is important to note that individual factors such as climate, building design, insulation levels and other energy-saving measures also play a significant role. Typically, the most effective ways to improve the energy performance of a historic building are to control all sources of air leakage and have an efficient heat source (furnace, boiler or other) [13].

The age of a building's windows can affect the energy balance, primarily in terms of energy efficiency [14]. Over time, gaps or cracks can develop in the windows, allowing air to enter or leave the building (Fig. 4). This air infiltration can lead to drafts, loss of conditioned air and increased energy consumption as heating or cooling systems compensate for temperature changes.

Replacing historic windows with modern, airtight double-glazed units is one of the most expensive, short-lived, least effective, yet most popular ways to reduce energy consumption in historic buildings [15]. Sometimes manufacturers of new windows commonly boast of low *U*-values. However, *U*-values are often mistakenly reported as the value for the entire window, when in fact it is the value for the centre of the glass (the place with the best *U*-value), not the sash or the average for the entire window. To be sure the data is properly presented, ask for *U*-values published by the National Fenestration Rating Council (NFRC), which assesses the performance of the entire window. When *U*-values are realistically presented for the entire window assembly, they are often much worse (i.e., higher) due to infiltration around the frame and unevenness of the opening. To compare windows in a scientific way, you must first calculate and measure the entire window, not just the glass. Second, you need to compare windows with the same dimensions and with exactly the same frame and glazing bars. It is also important to pay attention to comparative analyses: some manufacturers of replacement windows compare their window units to an "equivalent" single-pane aluminium window [3].

Heat loss/heat gain

Heat losses are often discussed, while heat gains remain marginalized. In summer, heat gains can significantly increase the energy costs associated with cooling a building. Long wavelengths of the daylight spectrum that enter through the glass must be able to exit, otherwise they turn into heat, which must then be absorbed by the building's cooling system. Glass with a low heat transfer coefficient ("low-e" or "soft low-e") performs this task best, improving thermal performance by reflecting infrared (long-wave) radiation reachingthe window.

Infiltration of outside air – not heat lost through the glazing – is the main culprit affecting the heat balance. It can account for up to 50% of a building's total heat loss [3]. When retrofit windows are installed on or within an existing window frame, the argument for preservation already exists: restoring the integrity of the fit between the frame and the building wall should be the priority of a preservation

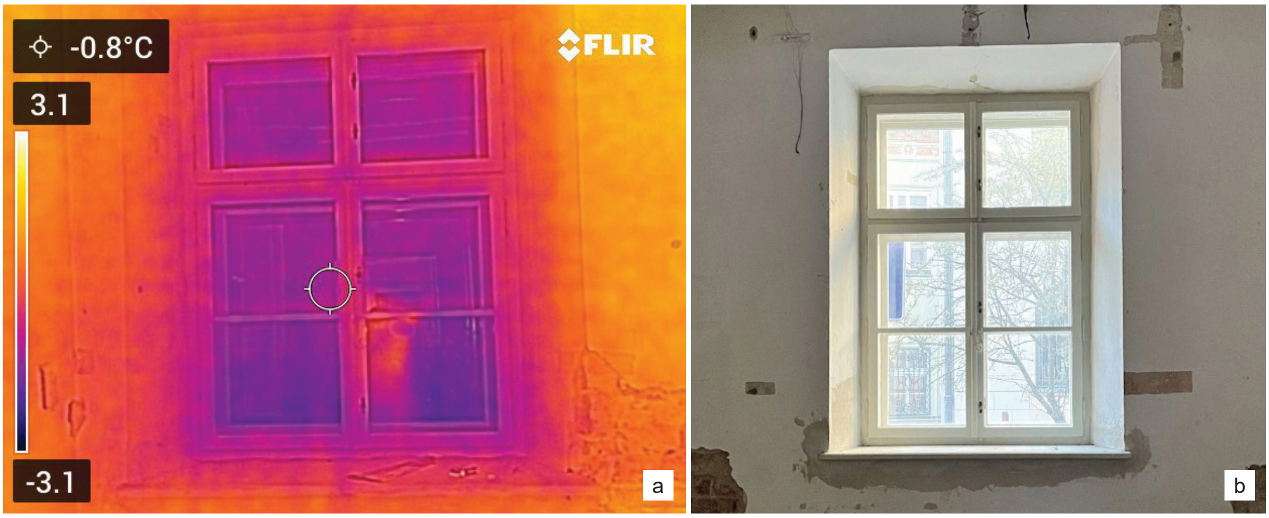

Fig. 4. Cracow, Poselska 7, historic window joinery:
a) photo taken with a thermovision camera showing heat loss within the window, b) existing condition of the window (photo by D. Strzałka-Rogal)

Il. 4. Kraków, ul. Poselska 7, zabytkowa stolarka okienna:
a) zdjęcie wykonane kamerą termowizyjną ukazujące utraty ciepła w obrębie okna, b) obecny stan okna (fot. D. Strzałka-Rogal)

approach. Sash pockets, pulleys and rails are areas prone to air infiltration in double-hung windows. Replacement window manufacturers themselves acknowledge that even in replacement, double-hung windows present the greatest challenge in terms of reducing heat loss, as infiltration occurs most often at the sash-sash and sash-frame interface, which is highly dependent on the quality of installation [4].

Insulated glass

Listed windows almost always contain insulating glass units. The effectiveness of double glazing depends largely on the depth of the air space between the inner and outer panes, as well as the type, type and amount of desiccant and gaskets used around the perimeter of the glass. Although Insulated Glass Unit (IGU) manufacturing techniques continue to improve, replacement in the event of failure is difficult and time-consuming, and the extra weight and thickness of IGUs prevent their use as retrofit elements in historic wood or metal sashes [4].

Laminated glass as an alternative

Laminated glass remains an often overlooked alternative to insulating glass units, perhaps due to the industry's emphasis on advertising it as "safety" glass. While laminated glass cannot compete with high-tech, complex insulating glass units, it does offer better *U*-values[4] than monolithic glass, without having to significantly alter the mullions of the historic sash in which it is installed. It should be remembered, however, that the *U*-factor is not the only criterion for determining the relative thermal efficiency of a window. Light and solar transmittance also affect the window's properties, and the benefits can be greater if laminated glass is chosen. It is worth noting that for historic buildings, the heat transfer coefficient *U*[5] may not be the same as for newly built buildings or other non-historic buildings undergoing thermal upgrading[6] [16]. On the one hand, energy audits, improvement of the emissivity of buildings, environmental certificates are imposed on investors, and on the other hand, the circles lobbying these trends turn a blind eye to such aspects as the carbon footprint of manufactured plastic windows.

Studies show that the best solutions in terms of energy, and thus heating economics, are achieved by keeping the existing wooden windows in older houses and retrofitting them with interior double-glazed windows with energy-efficient glass or glazing [4].

Sustainability

When properly repaired and upgraded, old windows can usually be brought to a condition comparable to new windows. This approach is "sustainable" on many levels.

[4] The heat transfer coefficient *U* indicates how much energy (expressed in watts) penetrates 1 m^2 of a partition (wall, roof, window, door) when the temperature difference on either side of it is 1 K. The unit of heat transfer coefficient is $W/(m^2\text{-}K)$. Typical differences in *U*-values can be: for single glazing: 4.8–5.8 W/m^2K, for double 1.2–3.7 W/m^2K (depends on the type), and for triple <1 W/m^2K.

[5] The Deutsches Institut für Normung standard specifies that the external wall *U*-value should be 0.20 $W/(m^2\text{-}K)$, for historic buildings insulated from the outside it allows $U = 0.45$ $W/(m^2\text{-}K)$, and for buildings insulated from the inside, especially for frame buildings, it allows $U = 0.65$ $W/(m^2\text{-}K)$. It is not possible to treat historic buildings the same way as buildings currently under construction and strive at all costs to achieve a *U*-value for exterior walls at the statutory level – currently 0.20 $W/(m^2\text{-}K)$.

[6] According to Article 3, paragraph 4, first indent of the *Ustawa z dnia 29 sierpnia 2014 r. o charakterystyce energetycznej budynków* [Law on Energy Performance of Buildings], the obligations to prepare an energy performance certificate do not apply to buildings subject to protection under the provisions on the protection and care of historical monuments [16].

Retrofitting is generally less costly than collective replacement and preserves the greatest amount of historic material. It also allows preservation of the invested energy put into material processing, labour, transportation. Embedded energy is lost when windows go to the landfill. Scrapping must also be added to the costs incurred [3].

In addition to the loss of architectural value as a result of replacing carpentry elements, a lot of technical damage to the building is observed. Old windows are often constructed of old lumber with good structural details, making them more durable and easier to maintain than new replacement windows [17]. With proper maintenance, they can last for decades, and repair costs over the life of a building are less than the cost of periodic replacement [18]. Repair costs typically also represent an investment in labour that benefits the local economy and does not involve gathering resources or shipping products from a distant production site [5]. Sustainable construction is about using fewer non-renewable resources. The goal of preservation and renovation by eye will not just be to reduce the monthly heating bill, but the overall and long-term environmental impact of the actions taken [19]. Wasting the energy used to extract raw materials, manufacture, transport, install and maintain an existing window worsens the overall balance of energy.

Conclusions

Based on the analysis of research results presented in selected literature, it can be concluded that the preservation of historic window frames affects the success of the building renovation carried out. At the same time, improving the thermal and functional parameters of old windows, while respecting the historic character (and often even saving money) is possible [8]. When examining old original wooden windows (pre-1950) that are being replaced with new double-glazed windows, it can be seen that many of them are in excellent condition and that they can be easily repaired and energy upgraded at a much lower cost than replacing them with equivalent new double-glazed windows [2]. In a situation where old original wooden windows in historic buildings can achieve better energy performance, have less maintenance, and have a lifespan 10–20 times longer than equivalent new double-glazed windows, there is no energy or economic argument, let alone an environmental one, in favour of replacing old windows with new double-glazed windows [5].

In fact, replacement windows can have unrealistic payback periods, and many are difficult to maintain and preserve. In many cases, given the life-cycle costs and maintenance of the historic fabric, repairing and restoring historic windows proves to be not only environmentally and aesthetically sound, but also economical [20]. Alternative materials, such as aluminium or vinyl and fiberglass, which have been used to replace historic original windows, result in a short lifespan. The decision to replace or refurbish windows also requires thinking in terms of sustainability. The author points out the trade-off between material gains and the long-term impact of the action taken, not only on the building in question, but also on the architectural, environmental and economic context, in order to find appropriate energy efficiency solutions.

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Streszczenie

Okna historyczne oraz ich wpływ na bilans energetyczny budynku

W związku z tym, że coraz większy nacisk kładzie się na to, aby istniejące budynki były energooszczędne, wymiana okien w obiektach o zabytkowym charakterze stała się tematem ważnym i kontrowersyjnym. W prezentowanej pracy przedstawiono współczesne tendencje o zasięgu europejskim i światowym dotyczące wymiany historycznej stolarki na nową. Na podstawie analizy literatury przedmiotu omówiono zagadnienia konserwacji, naprawy i termomodernizacji starych okien, by spróbować określić, w jaki sposób oraz w jakim stopniu wymiana nie tylko niekorzystnie wpływa na estetykę budynku, ale również na aspekt ekonomiczny i ostateczny bilans energetyczny budynku. Celem artykułu jest ukazanie zabytkowego okna jako detalu architektonicznego, który warto za wszelką cenę zachować podczas przeprowadzanej renowacji budynku, modernizując je w taki sposób, by sprostało współczesnym wymogom energetycznym. Autorka zwraca w pracy uwagę także na kwestię zrównoważonego rozwoju oraz szacunek do otaczającego dany obiekt dziedzictwa architektonicznego.

Słowa kluczowe: okna historyczne, renowacja, zrównoważony rozwój, bilans energetyczny