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Smart and Healthy within the 2-degree Limit

Wooden windows in the historic alpine architecture:

Balancing energy and conservation needs

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1. INTRODUCTION

Historic buildings account for a large fraction of the residential built stock. In countries like the UK, Spain, Denmark or France, more than 20 % were built before 1919 and almost 40% before 1945. In order to minimise climate change and stay within the *2 degree limit*, national and international mandates on energy efficiency are putting significant pressure on the built heritage that generally underperforms compared to modern buildings. Energy retrofit of historic buildings could cut up to 180 Mt of CO_2 emissions annually [1].

Windows are a significant source of heat loss in historic buildings [2]. Thus, improving their performance could have a major impact on the energy consumption of the built heritage. Nevertheless, windows shape the building from an architectural point of view. In addition to that, in those cases where the original materials have been preserved, windows are witnesses of the artistic, technical and manual possibilities of a period.

The substitution of original wooden single glazed windows with standardised efficient units has thus an unacceptable impact on the external appearance of historic buildings. Moreover, very little attention is paid to the changes in the hygrothermal behaviour of the building increasing the risk of mould growth and condensation. Therefore, new heritage compatible solutions are urgently needed. This paper explores sympathetic retrofit alternatives that improve historic wooden windows' performance while respecting their history and value.

2. SCOPE AND METHODOLOGY

Work on historic windows has mainly been focused on the thermal performance of glazing and there is still a significant lack of understanding around how the other components of traditional windows (frame, edge bond, glass-dividers or shutters) can be improved to enhance the overall thermal performance of the installed window and to ensure moisture protection.

This paper will therefore focus on two aspects: (i) the conservation compatible improvement of existing windows and (ii) the connexion between the wooden frame and the wall in those cases were the window should be replaced with a heritage compatible solution.

A desk-based analysis of historic alpine window construction allowed the identification of promising opportunities of the intervention in the cases where the original window should be maintained. The exploration of new disciplines allowed the identification of suitable solutions that could solve the limitations of historic windows.

The window-wall connection was analysed in several steps. First, a series of workshops with window manufacturers was organised to investigate the current practice an understanding of local trades. Following, the current approach for window renovation used in the area was investigated and evaluated by means of numerical simulation with a two-dimensional building heat-transfer modelling software. Starting from that snapshot, the window-wall connection was optimized reducing at maximum the number of components and the energy losses, assuring an airtight connection and moisture protection.

3. NEW SOLUTIONS FOR OLD WINDOWS

Studies led by Historic England [3] and Historic Environment Scotland [4] found that shutters are the most effective traditional method of reducing heat loss through timber sash windows. However, whereas in England and Scotland shutters are placed inside and can be folded with the internal panelling, in the alpine region shutters are traditionally placed outwards and fold against the external wall. These therefore require a different approach towards their retrofit that has not yet been explored. Moreover, in some areas of the alpine region, it was custom to replace the wooden shutters with a second glazing layer during the coldest months. These "*winterfenster*" (or winter windows) enhanced solar gains while minimising heat losses [5].

Where wooden shutters are used all year around, combining insulation and materials with high thermal inertia (such as PCM) in shutters would allow not only to reduce the heat loss through the opening at night, but also to make use of the solar gain accumulated during the day when the shutters are open and exposed to the sun. Moreover, embedded PCM in shutters could also moderate the internal climate in summer minimising the increased risk of overheating caused by internal wall insulation. Research developed to date have not addressed the performance of traditional shading devices and the potential of solar energy in historic buildings or have proposed solutions that would not be compatible with the built heritage.

Alternatively, reinstating the traditional practice of using removable secondary glazing in winter would be a solution to minimise the heat loss. These temporary interventions would reduce the overall U-value and air infiltration of the window, while respecting the conservation and aesthetics of the façade.

4. IMPROVING THE WINDOW-WALL CONNECTION

Wooden windows play an important role in alpine construction with different particularities between regions. For instance, in South Tyrol (northern Italy) wooden windows are very present in new building constructions and in retrofits, especially in case of protected historic buildings. Respect to other European regions, a particularity in Tyrol is the use of a hidden sub frame when installing the window into the wall. While numerous South Tyrolean window manufacturers develop high-quality windows, the development of the window-wall connection is often neglected.

A workshop that brought together researchers, planners and craft companies identified two main problems in recently renovated historic buildings: an increase in the airtightness without raising the ventilation rate accordingly and an improvement of the thermal performance of the window without enhancing the thermal insulation of the wall around it. This has led to scenarios of mould growth and condensation risk.

Regarding the optimal design of the window-wall connexion, three aspects therefore have to be assessed: (i) internal surface temperatures, (ii) heat losses through the thermal bridge and (iii) connection airtightness.

Due to the specificities of historic buildings, tailor made solutions are often needed. In the example presented in fig 1, a 16th century building in the historic city centre of Bolzano (Italy), the substitution of the window resulted in high mould growth risk on the window reveal. As internal insulation is not possible in the major part of the case study, the junction could be optimised by applying a thin layer of insulating plaster on the window reveals (fig 1.b). In this particular case, thermal heat losses could be reduced even further as we found a cavity behind the existing plaster where it was possible to insert an insulation layer of 4-6 cm (fig 1.c). This allowed an increase the surface temperature in the critical points to ensure a moisture free connection.

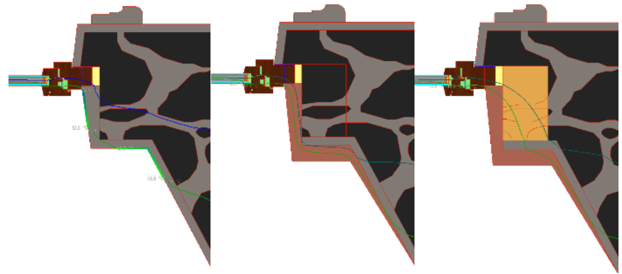

Figure 1: Optimization of the window-wall connection

5. CONCLUSION

In cases where existing windows cannot be replaced we identified innovative approaches to reduce the heat loss from the glazed elements operating on the outer layers with respect to the windows. We propose two strategies: (i) thermal improvement of wooden shutters with the addition of an insulating layer and with the use of PCM coatings and (ii) the reinstatement of the traditional secondary glazing approach with the use of high thermal quality glazing.

In cases where it is possible to replace existing windows, we identified the deficiencies of the current solutions. In particular, the biggest issue turned out to be a lack of attention in the study of the window-wall connection detail leading to an increase of the risk of mould formation in the reveal area.

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