Retrofitting balcony doors from the 1950s: feasibility study of VIPs

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Retrofitting balcony doors from the 1950s: feasibility study of VIPs

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Abstract
By combining necessary renovation measures with energy efficiency retrofitting measures, there is potential for energy savings and reduced carbon dioxide emissions. One benefit of these measures is the increased thermal comfort for the occupants in the building. In listed buildings, windows and doors are often parts that are difficult to impose energy efficiency retrofitting measures on because of the protection against changing the appearance of the building. Traditionally, balcony doors consisted of an upper glazed part and a lower opaque part, which was rarely properly insulated by the standards of today. The energy use for heating can be decreased by installing insulation in this lower opaque part of the door while increasing the thermal comfort. This study investigates a housing area from the 1950s with 220 balcony doors. The lower opaque part of the door today consists of a 12 mm thick sheet of porous wooden board. The study aims to evaluate if the thermal performance of the lower part of the door can be improved without changing its aesthetics. The improvement should be economically sound with a low environmental impact. Three different types of thermal insulation were compared; glass wool, expanded polystyrene (EPS), and vacuum insulation panel (VIP). The thickness of all materials was 10 mm. Calculations of the thermal, moisture, economic and environmental performances were done for the three materials. The results show that the EPS and glass wool have a payback period of 57 years, while VIP, due to the much higher thermal resistance, has a payback period of 17 years. Despite the higher investment cost for the VIP, this study shows that the material is beneficial due to its higher thermal resistance compared to conventional insulation materials.

Keywords: vacuum insulation panel; renovation; door; energy efficiency

1. Introduction

The focus on energy efficiency measures and cut carbon dioxide emissions from the building sector creates many challenges. One of these is how to balance the conflict between energy efficiency and heritage values in buildings. Another challenge concerns the moisture performance of the building after it is renovated. One of the most common causes for retrofitting the building envelope is that there are acute failures in building components due to exceeded service life. This is especially a challenge in buildings located in areas of national interest for cultural heritage and for buildings that are listed. Buildings from before 1945 in Sweden are the buildings with one of the largest energy efficiency potentials of the building stock. Often, these buildings have character defining elements that make them difficult to retrofit. Also, there are problems with the building components, technical service life and unacceptable indoor thermal comfort. Conventional insulation materials have a thermal conductivity which requires a certain thickness to achieve a satisfactory thermal transmittance, U-value, of the building component. Vacuum insulation panels (VIP) have a 5-10 times higher thermal resistance compared to conventional materials which create new possibilities when imposing energy efficiency measures in listed buildings.

Windows and doors are often parts that are difficult to impose energy efficiency retrofitting measures because of the protection against changing the appearance of the building. Traditionally, balcony doors consisted of an upper glazed part and a lower opaque part, which was rarely properly insulated. By installing insulation in the lower opaque part of the door, the energy use for heating can be decreased while the thermal comfort is increased. This study investigates a housing area from the 1950s with 220 balcony doors in need of renovation. The lower opaque part of the door consists of a 12 mm thick sheet of porous wooden board. The aim of the study was to evaluate if the thermal performance of the lower part can be improved without changing the aesthetics. The improvement should be economically sound and have a low environmental impact. Three different types of thermal insulation were compared; glass wool, expanded polystyrene (EPS) and vacuum insulation panel (VIP). The thickness of all materials was 10 mm. Calculations of the thermal, moisture, economic and environmental performance was done

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for the three materials. The results of the economic evaluation is presented and discussed here while the other parts are presented in [1].

2. Case study area in Gothenburg, Sweden

The housing area consist of 196 apartments in several three-story buildings. The area was constructed by a private housing cooperative in 1948-1950. During the last years, infrared thermography has been used to identify thermal bridges in the buildings. One of the major thermal bridges consist of the opaque part of the balcony doors, see Fig. 1. This part can become very cold during wintertime and create a cold surface on the inside that has led to complaints on insufficient thermal comfort from the members of the housing cooperative. To improve the situation with the insufficient thermal comfort and decrease the energy use in the buildings, one of the proposed measures is to install insulation in the opaque part of the balcony door. Due to the limited space available it is possible to install only 10 mm insulation.

Fig. 1. The balcony door with the upper glazed part and the lower opaque part, insulated with a 12 mm wooden board. Photo: Alexander Sehlström.

The door is composed of a connected wooden frame, width 65 mm, in which two single-glazed windows are installed. The lower opaque part is 36 mm thick in total. The U-value of the glazed upper part is around 2.5-3.5 W/(m^{2}K). By replacing the glass panes with a modern double or triple gas-filled glazing unit a lower U-value could be achieved, but at the expense of damaging the original appearance. The airtightness of the door has not been investigated further in the study but replacing the sealing joint around the connected wooden frame could lead to reduced draft of cold air. The properties of the three insulation materials are presented in Table 1.

Table 1. Properties for thermal, moisture, economic and environmental performance evaluation.

Material	Thermal conductivity (W/(m·K))	Vapor permeability (·10^{-6} m^2/s)	Investment cost* (€/m^2)	GWP (kgCO$_2$-eq/m^2)
Glass wool	0.036	24	1.1	0.17
EPS	0.036	0.6	1.9	1.11
VIP	0.008	0.005	30	3.03
Wooden frame	0.14	0.9	-	-
Wooden board	0.05	4	-	-

* Price for 10 mm thickness, 1 € = 10 SEK, Reference: Beijer bygg.

3. Economic evaluation

The energy savings were calculated by comparing the transmission losses through the original door layout with the transmission losses of the doors with the compared insulation materials. The total energy savings during a year was calculated by using the indoor temperature 20°C and the monthly average outdoor temperature. Table 2 present the results for the transmission losses through each door composition compared to the original layout. The heating energy is calculated only for months that have an average outdoor temperature below 11°C. The building is heated by district heating with a cost of 0.085 €/kWh.

Table 2. Thermal resistance of each composition, transmission losses, heating energy and associated operating cost per door, based on monthly average outdoor temperature and indoor temperature 20°C.

Composition	Thermal resistance (m^2K/W))	Transmission losses (kWh/year)	Heating energy (kWh/year)	Operating cost (€/year)
Original*	0.24	102.7	85.3	7.2
Glass wool	0.28	87.3	72.5	6.2
EPS	0.28	87.3	72.5	6.2
VIP	1.25	36.8	30.6	2.6

* 12 mm sheet of porous wooden board insulation.

The annual energy savings is calculated by subtracting the heating energy use for each composition from the heating energy for the original door composition. The total investment cost for the installation of the insulation materials depends on the time for the installation and the hourly labor cost. In this study, the time for the installation is assumed to be 1 hour/door, independent on the material, and the hourly fee is 65 €/hour. The amount of insulation per door is 0.45 m^2. The investment cost is presented in Fig. 2.

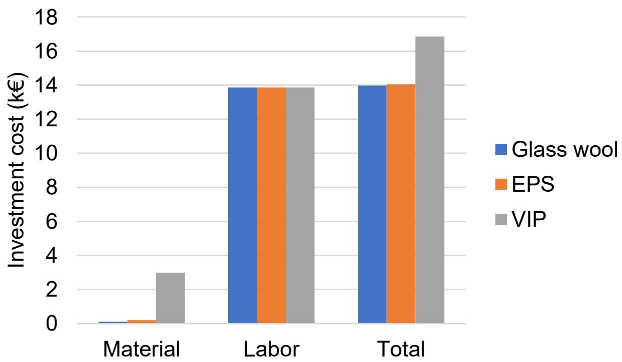

Fig. 2. Total investment cost for all 220 doors in the private housing cooperative, distributed on material cost and hourly labor fee.

4. Results and discussions

In this study thermal, moisture, economic and environmental performance was evaluated for the three materials compared to the original door composition. The result of the economic evaluation is presented and discussed here while the other parts are presented in [1]. As presented in Fig. 2, the material cost is a minor part of the total investment costs. In fact, the payback period for the investment is 57 years for the glass wool and EPS, while for the VIP the payback period is 17 years. This is under the assumption that the required installation time is the same for each material.

The investment cost of installing insulation in the opaque lower part of the door can be compared to other retrofitting measures. One of these is to change the two single-paned windows in the upper part of the door to a modern double or triple gas-filled glazing with low emissivity coating. This would reduce the U-value of the window and lead to energy savings of between 93 kWh/year and 177.5 kWh/year. Another retrofitting measure is of course to replace the entire balcony door. This is probably not possible due to the demands on the preserving the exterior character defining elements. The overall thermal transmittance (U-value) of the original door is approximately 2.15 W/m^2K, while a new door is around 1 W/m^2K. This measure would save around 240 kWh/year which is substantially more than just replacing the upper glazed part and adding insulation to the lower opaque part. However, the payback period would become 23 years (excluding labor costs) which is substantially more compared to retrofitting using VIP which was 17 years.

5. Conclusions and outlook

This study investigates a housing area from the 1950s with 220 balcony doors in need of renovation. The aim of the study was to evaluate if the thermal performance of the lower part can be improved without changing the aesthetics. Traditionally, balcony doors consisted of an upper glazed part and a lower opaque part, which was rarely properly insulated. By installing insulation in the lower opaque part of the door, the energy use for heating can be decreased while the thermal comfort is increased. The payback period of the retrofitting measure is highly dependent on the time of the installation and the hourly labor fee. With the assumptions made in this study the payback period is still too long for the private housing cooperative to invest in the retrofitting measure. However, with increasing costs for heating energy in the future similar measures may become economically feasible soon.

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References

[1]. J. Lahti, A. Svensson, Renovering av balkongdörrar i 50-talshus: Jämförelse mellan olika isoleringsmaterial [Renovation of balcony doors in 50's houses: With a focus on replacing the insulation] (In Swedish), Degree Project in the Engineering Programme Civil and Environmental Engineering, Chalmers University of Technology.