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# Evaluation of 5 years' performance of VIPs in a retrofitted building façade

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ABSTRACT

The challenges to retrofit buildings urges for technologies and novel building materials to be developed. In many cases the space for additional insulation in the building envelope is limited. Vacuum insulation panels (VIPs) have a significantly lower thermal conductivity than conventional insulation materials which means less thickness is required to achieve the targeted thermal transmittance. VIPs have been used in buildings since the late 1990s and there exists experience from using them in numerous applications. Besides the higher initial cost for using VIPs in buildings there is still hesitation among architects and engineers whether this component will withstand long-term use in buildings. Therefore further investigations are needed to evaluate its long-term performance. This paper presents experiences from a case study of a previously non-insulated wall insulated with VIPs. Measurements of the temperature and relative humidity in the wall during 5 years show no sign of deterioration of the VIPs and there is a low risk for condensation in the construction. The measurements are continuous with the aim to determine the long-term performance of VIPs in building applications.



## 1. Introduction

During the 1930s and 1940s the modern Swedish housing policies were decided. Investigations of the general living conditions in Sweden were used to establish guiding principles for how a healthy and modern dwelling should be constructed. Old buildings in densely populated areas in the cities were demolished and replaced with modern buildings in new residential areas. These areas were constructed in the 1960s and 1970s, during the so-called million programme (1964–1975), when 1 million dwellings were built in Sweden. Today around 20% of the Swedish building stock was built during the million programme, see Fig. 1 (left). This is a substantial share of the building stock, but the percentage of buildings from before this time period is even greater with 47%. The buildings from this period are also the ones with the highest thermal transmittance (U-value, W/(m$^2$ K)) in the exterior walls of all the building stock, as shown in Fig. 1 (right). The average U-value is around 0.58 W/(m$^2$ K) while it is 0.42 W/(m$^2$ K) for buildings from the million programme [1] which should be compared to the current building regulations which recommend a U-value of 0.18 W/(m$^2$ K) [2]. The old buildings are now in need of retrofitting measures. In fact all buildings from the time before 1975 have to be retrofitted before 2050. This is close to two million apartments which is three times more than what will be built until 2050. To reach the energy reduction targets by 2050 in Sweden, the retrofitting measures should include measures for improved energy performance [3].

There are many aspects, besides energy performance, that have to be considered in every building project. For renovation and retrofitting projects it is even more complex since there are several stakeholders who all have their views on how the project should be implemented. From a societal aspect legislation on e.g. accessibility, architecture, thermal comfort, ventilation and historic context makes the number of solutions that is possible for each project limited. The property owners want to maximize the profit while the tenants want to minimize the rental cost. These questions have been discussed ever since the first buildings were constructed. Today many buildings that have been retrofitted stand for their second or even third retrofitting. Following the retrofitting measures used in the 1970s and 1980s the appearances of many buildings were changed. With new technologies and improved measures some of these changes could be reversed to bring back lost building qualities while the energy performance is maintained. These solutions need to be evaluated and studied during a longer time perspective since buildings typically are designed for a service life of 80–100 years.

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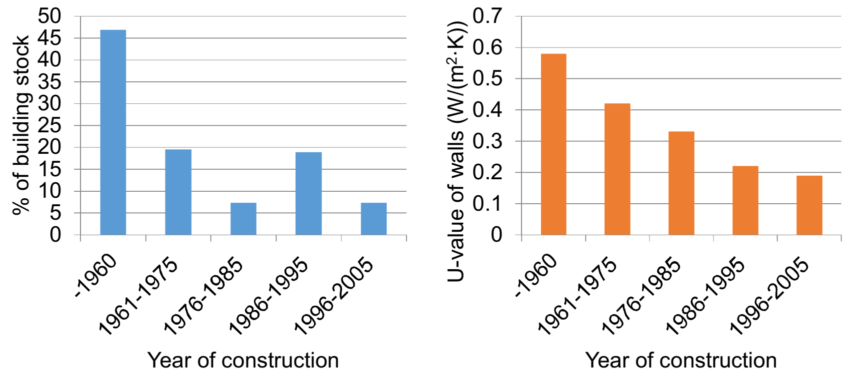


**Fig. 1.** Left: Percentage of the multi-family building stock from different time periods. Right: Average U-value of the exterior wall in buildings from different time periods [1].

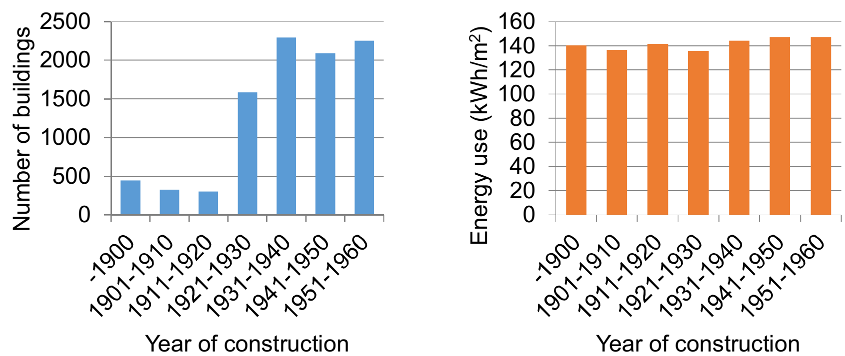


**Fig. 2.** Left: Number of multi-family buildings in Gothenburg from different time periods. Right: Average energy use for space heating, cooling, domestic hot water and facility electricity in builidings from different time period.

The technical documentations and drawings of old buildings are often of bad correspondence with the present conditions or completely lacking. The Swedish National Board of Housing, Building and Planning (Boverket) concluded that out of 1 800 investigated buildings, 40% had technical documentations and drawings that could not be used or were completely lacking [4]. This makes the knowledge of the energy performance of large parts of the building stock hard to evaluate. However, since 2006 the Energy Performance of Buildings Directive (EPBD) [5] requires Energy Performance Certificates to be issued for all buildings. In Sweden, these are based on the measured energy use for space heating, cooling, domestic hot water and facility electricity during 12 consecutive months for normal use during a reference year (30 year average). As an example the energy use in 9 291 buildings from before 1961 in Gothenburg in the south of Sweden is presented in Fig. 2. The buildings are divided on the number of buildings from different decades (Fig. 2 left) and their average energy use (Fig. 2 right).

The measured energy use in these old multi-family buildings is on average between 136 and 147 kWh/m$^2$ for the different time periods. However, to reach the goals of less greenhouse gas emissions in society, the energy use has to be further decreased to an average energy use of 92–102 kWh/m$^2$ by 2050 [4]. As discussed above, one way to reduce the energy use is to insulate the building envelope. However, in many cases the space for fitting additional thermal insulation in existing buildings and systems is limited. Therefore, super insulation materials with lower thermal conductivity than seen before are being developed. One of these components is the vacuum insulation panels (VIPs) which have been used in buildings since the early 1990s. A VIP is composed of mainly two parts; the core material and the surrounding envelope. The core material (often fumed or precipitated silica) is evacuated and wrapped in a metalized multi-layered polymer laminate. The resulting center-of-panel thermal conductivity is less than 4 mW/(m K). The thermal conductivity increases by time due to air and moisture diffusion through the laminate. Also, the laminate itself creates a thermal bridges around the panel. Therefore, the declared thermal conductivity of a VIP is 7–8 mW/(m K). A fully air filled VIP with fumed silica core has a thermal conductivity of 19–20 mW/(m K).

The first applications of VIPs in buildings were realized in the late 1990′s why the long-term performance of VIPs in real conditions is not yet known. A study by Simmler and Brunner [6] showed that VIPs available a decade ago typically have a service life of around 25–40 years, which is much shorter than for a building but similar to most other building materials. The service life was confirmed by Wegger et al. [7] who re-evaluated the performance of VIPs with various barrier laminate solutions over time. They found that accelerated ageing in the laboratory had little effect on the thermal performance of the VIPs but also that some of the tested conditions were too severe to evaluate the performance properly. Therefore, in 2013, the IEA EBC Annex 65 'Long-Term Performance of Super-Insulation in Building Components & Systems' was initiated which will study the long-term performance of several super insulation materials. The long-term performance of the VIPs is one of the focus areas which will generate new knowledge and better predictions of the long-term durability of the VIPs. This paper is a continuation and follow-up on the study presented in [8] and introduces a broader discussion on the long-term hygrothermal performance started in [9] and [10]. The aim of this paper is firstly to present an analysis of the long-term performance of VIPs in a retrofitted exterior wall. Secondly, the aim is to explore and evaluate the use conditions in the building and show that potential built-in moisture in the wall still has the possibility to dry out, and thirdly to investigate the influence by thermal bridges around the