Vacuum Insulation Panels in the Building Sector

A. Binz and G. Steinke

Institute of Energy in Building, University of Applied Sciences Northwestern Switzerland (FHNW), St. Jakobs-Strasse 84, 4312 Muttenz, Switzerland, www.fhnw.ch/habg/iebau

ABSTRACT

Used in buildings, vacuum insulation panels (VIP) enable thin, highly insulating constructions to be realized for walls, roofs and floors. The introduction of these novel insulation elements in the building trade, however, is hampered by many open questions and risks. Subtask B of the IEA/ECBCS Annex 39 illustrated with a wide selection of reports from practice, how the building trade deals with this new insulation elements today, the experience gained and the conclusions drawn there from. In this paper recommendations for the practical use of VIP are given, and also questions regarding the effective insulation values, ecological effects and benefits of use are discussed.
The results of the Annex 39 give an important basis for the current Swiss research activities on vacuum insulation focussing on practical applications. Five different projects developing building systems with VIP funded by the Swiss Federal Office of Energy are presently in progress.

KEYWORDS

Vacuum insulation panel, effective thermal conductivity, recommendations for practical use, development of building systems

VIP IN THE BUILDING SECTOR – SYSTEMS AND APPLICATIONS IEA/ECBCS ANNEX 39 SUBTASK B

Introduction

To meet today’s ambitious building standards, such as the passive-house-standard, often high requirements to the thermal performance of the building envelope have to be fulfilled. The application of 25-35 cm of conventional thermal insulation could cause technical and aesthetical problems, particularly at refurbishment of existing buildings. Compared to the enormous progress with transparent building components in the last decades, the improvement of the thermal performance of opaque components was only moderate so far. Here the application of Vacuum Insulation Panels (VIP) opens up new potentials. Their insulation performance is a factor of four to eight times better than that of conventional insulation. They enable thin, highly insulating constructions to be realized for walls, roofs and floors. The introduction of these novel insulation elements in the building sector, however, is accompanied by many open questions and risks.
In the time period 2001-2005 an international research team worked on the topic of vacuum insulation for buildings. The research was done within IEA/ECBCS Annex 39 „HiPTI – High Performance Thermal Insulation“ and was funded in Switzerland by the

Swiss Federal Office of Energy. Whereas Subtask A dealt with basic questions of vacuum insulation, Subtask B was focused on practical aspects of the application of vacuum insulation in the building sector. The participating research teams from Switzerland (lead), Germany, Netherlands and Sweden published the final report in summer 2005, Binz et al (2005).

The core part of the final report of Subtask B consists of practice reports, showing actual examples where vacuum insulation panels (VIP) have been used. A wide range of built examples, such as floor and ceiling constructions, terrace insulation, non-loadbearing sandwich elements, parapet insulation, prefabricated façade elements etc. form a rich basis of experience for interested planners and experts as well as manufacturers in search of new products with integrated VIP. Furthermore, the report states the actual knowledge on reliability, thermal bridge effect of the panel envelopes, i.e. the effective thermal resistance of VIP, and recommended constructions with VIP.

Ageing effects – Swiss design values

The thermal conductivity of a well evacuated dry VIP with a fumed silica core is typically about 0.004 W/(m·K) after production, measured in the centre of a large panel. In the course of its life in a building construction, a VIP will take up small amounts of air and water vapour through the welding seams and pinholes in the laminate. This raises the internal pressure and moisture inside the panel. Due to this process the thermal resistance is lowered slowly. Table 1 shows a recommendation for design values for Switzerland, based on numerous studies on ageing effects which were conducted within the IEA/ECBCS Annex 39.

Table 1:
Centre-of-panel thermal conductivities (λ_{cop}) for aluminium and polymer based multiple metallized barrier envelopes (safe values) which are used in Switzerland.

centre-of-panel conductivity values		λ_{cop}
AF: aluminium foil films	[W/(m·K)]	$6 \cdot 10^{-3}$
MF: metallized polymer films	[W/(m·K)]	$8 \cdot 10^{-3}$

Thermal Bridging - effective thermal conductivity of VIP

In addition to the ageing effects thermal bridging of the panel edge, joints between VIP and mounting parts have to be considered. Due to thermal bridging of the panel edge the effective or overall thermal conductivity, λ_{eff}, of the vacuum insulation panel is higher than the ideal centre-of-panel thermal conductivity λ_{cop}. The effective thermal conductivity of a VIP takes into account all non-homogeneities, originating from the product itself as well as from the joint between adjacent VIP.
The thermal bridge is also affected by the thermal properties of the material layers adjacent to the VIP. At the Empa the influence of various surrounding materials was investigated. The calculations were performed for a VIP (thickness 20 mm) with metallized barrier envelope for the adjacent materials metal, glass, wood and insulation, in each case without an air gap between the VIP and with a 5 mm air gap

between the panels (Figure 1). Adjacent material layers with a high thermal conductivity will cause a deterioration of λ_{eff} values. As far as possible, therefore, insulating materials, wood or other substances with low thermal conductivity should be used.

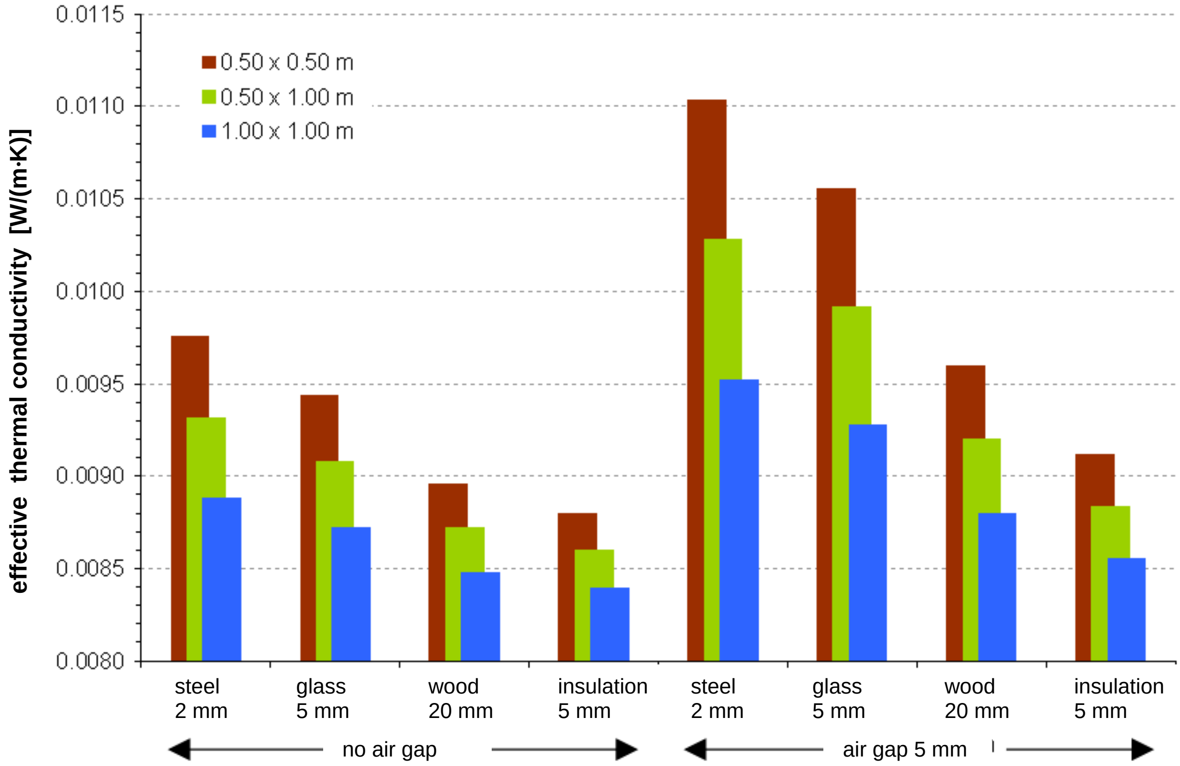


Figure 1: Effective thermal conductivity (λ_{eff}) of VIP layers. Different panel sizes, different materials and thicknesses of adjacent layers and different gap widths between panels were considered. Calculations based on a centre-of-panel conductivity of $8 \cdot 10^{-3}$ W/(m·K) as recommended for VIP with metallized envelope.

Ecology

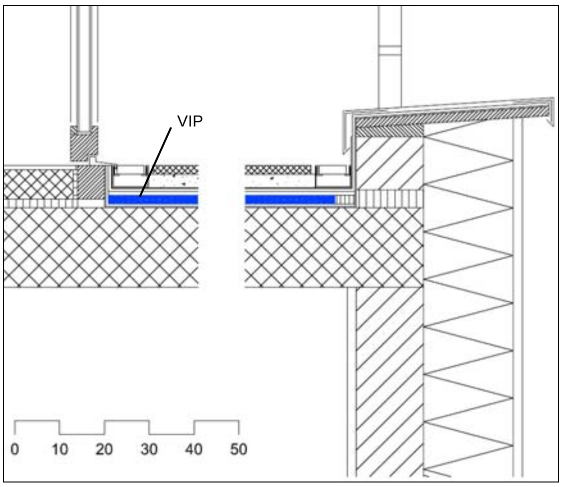
Within the scope of the IEA/ECBCS Annex 39, a detailed life cycle analysis (LCA) was performed at the University of Applied Sciences Northwestern Switzerland (FHNW), Institute of Energy in Building. The results show that the use of VIP in buildings leads to the same order of magnitude of environmental loading (or "unloading") as for conventional insulation materials. Since the overall pollution by insulation during the building process is small, one can give the "green light" to the use of VIP from an ecological point of view.

Practical use of VIP- benefits

VIP are significantly more expensive than conventional insulation materials. They will not displace the latter from the market, but will complement them in a realistic manner. The present price situation, however, is still dominated by the typical dynamics of the product introduction phase. Furthermore, the products themselves are still being developed, continually improved and they tend to become cheaper. Their extra price is in many cases justified by significantly increased benefits. The latter are mostly connected with space saving:

- *VIP enable to gain useful area*
  e.g. maximization of usable area when fixed dimensions for a building are given
- *VIP enable to raise comfort*
  e.g. insulation of flat roof terraces with VIP avoids high steps between the interior and the terrace
- *VIP enable to build*
  e.g. insulation of ceiling / floor with VIP at limited height dimensions
- *VIP enable to assure satisfactory thermal insulation*
  e.g. insulation of the gable of buildings having a small roof overhang
- *VIP enable to improve aesthetics*
  e.g. slim and highly insulated constructions for refurbishment

Nowadays in Switzerland VIP mainly are installed on the construction site. By far the most frequent use of VIP in Switzerland is the insulation of flat roof terraces (Figure 2).

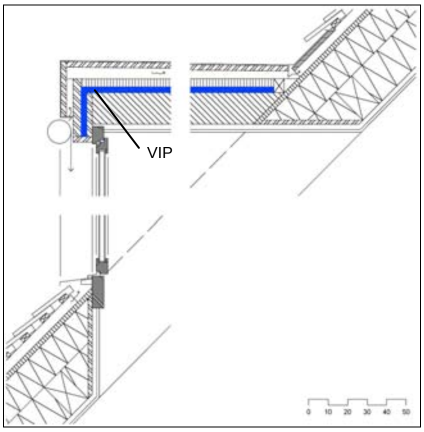


Terrace floor
construction (top down)

garden tiles 20 mm
flint (draining) 30 mm
mat
bitumen sealing
rubber meal mat 8 mm
VIP 20 mm
PE foam mat 5 mm
vapour barrier
concrete ceiling

Figure 2: The installation of VIP in roof terraces enables a simple constructive solution for a stepless transition from interior to terrace.

Although the processing of VIP in a factory under controlled conditions by specially trained personnel would be highly desirable, only a few prefabricated products and systems are available in the market today. Figure 3 shows a prefabricated dormer window that is attached as a ready-made element to the cut-out prepared in the roof. This construction was developed and realized for the renovation of an old building in Zurich / Switzerland. Owing to the two-layer, load-bearing, one can dispense with lathing between the VIP, which further reduces the heat losses.



Dormer Window
construction (outside in)

metal roofing
roof sheeting
three-layer board 27 mm
wooden laths 40-60 mm
protection mat
soft grain board 40 mm
VIP 30 mm
ceiling (solid wood)
vapour barrier
wooden laths
gypsum plaster board

Figure 3: View and detail of a prefabricated dormer window developed for the renovation of an old building in Zurich / Switzerland.
(Architect: Viridén + Partner AG)

Recommendations

To raise the confidence in VIP-technology and their use in building applications the following recommendations should be taken into account:

- *Industrial processing:* Integration of VIP in prefabricated building systems and components.
- *Information and consulting:* All concerned be informed, advised as early as possible and be supported by a specialist during the entire planning and installation process (preferably by the VIP supplier). Warning Label “VIP inside”.
- *Handling:* VIP must be handled with care and suitable protective measures and tools employed (protective mats, felt shoes, etc.).
- *Detailing:* VIP must be well protected from mechanical damage. This applies to functional loading (e.g. from the floor), inadvertent loading (e.g. dilatation) and subsequent manipulations (e.g. nailing). One must pay special attention to various joint details, since protecting components (e.g. angle brackets for window attachment, guide rails, frames) may damage the VIP. Tolerances of the panels in length and width of +2/-5 mm have to be considered.
- *Reducing the edge effect:* Select panels that are as square and large as possible (min. 0.5 x 0.5 m^2). Panel with an aluminium foil envelope (only rarely nowadays), lay the panels in a double layer, overlapping by at least 5 cm.
- *Water vapour diffusion:* VIP are vapour-tight insulation systems, which has to be taken into account in planning the order and thickness of the layers. Furthermore, special attention must be given to the joints between the panels.
- *Inspection of the VIP*: Installation of the VIP in such a way that inspection of their correct functioning can be made (sensor or thermography).
- *Replaceability:* It would be desirable, that the VIP are embedded in the construction such that they can be replaced without undue effort in preparation or as a result (e.g. mechanically fixed covers). Otherwise deterioration in the U-value has to be accepted and it must be assured that on loss of vacuum, there is no risk of loss of condensation and mould at the inside of the walls.

CURRENT VIP RESEARCH PROJECTS IN SWITZERLAND

The results of the IEA/ECBCS Annex 39 make clear, that there is a great potential for quality assured application of VIP in the building sector. To open up this potential the Swiss Federal Office of Energy decided mid 2005 to fund five different projects developing building systems with VIP:

- Further development, quality assurance and long-term behaviour of VIP with mechanical protection
  Project team: ZZWancor, Regensdorf; Empa, Dübendorf

- Development of building systems and components with VIP for façades
  Project team: Eternit AG, Niederurnen; swisspor AG, Boswil; va-Q-tec AG, Würzburg (Germany), Institute of Energy in Building – FHNW, Muttenz

- Development of a loadbearing thermal insulation element with fiber reinforced composites and integrated VIP
  Project team: Empa, Dübendorf

- Development of a façade element for low energy houses with vacuum insulation
  Project team: Renggli AG, Schötz; Dr. Eicher+Pauli AG, Liestal

- Development of a floor heating element with integrated VIP
  Project team: Tobler AG, Urdorf; Dr. Eicher+Pauli AG, Liestal

References

Binz, A., Cauberg, H., Erb, M. Heinemann, U., Johannesson, G., Simmler, H. et al (2005), *Vacuum Insulation in the Building Sector – Systems and Applications*, Annex 39 "HiPTI-high Performance Thermal Insulation " of IEA/ECBCS – Implementing Agreement, Report on Subtask B, (published on www.vip-bau.ch and www.vip-bau.de)