Applications of Vacuum Insulation in the Building Sector

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1 Introduction

Vacuum insulation panels (VIP) were already developed some time ago for use in appliances such as refrigerators and deep-freezers. Their insulation performance is a factor of five 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 such a novel material in the building sector, however, is accompanied by many open questions and risks.

In the time period 2002-2005 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“. Whereas Subtask A dealt with basic questions of vacuum insulation, Subtask B was focussed 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 2005].

The core part of the report of Subtask B consists of practice reports, showing actual examples where vacuum insulation panels (VIP) have been used, and discussing special issues and open questions. A wide range of built examples, all using VIP, 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 resulting thermal resistance of VIP, and recommended constructions with VIP. The results of Subtask B make clear that VIP’s have become a feasible and important mean for energy efficient buildings.

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: in some cases satisfactory insulation may not be possible at all with normal materials, in others useful area may be able to be gained or conserved owing to the lower thickness of vacuum insulation.

2 Properties of vacuum insulation panels

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. The mean thermal conductivity of an insulation layer consisting of VIP is increased by thermal bridges as a result of the panel edges with aluminized films. The effects of these thermal bridges are different depending on the laminate type, panel thickness and adjacent materials.

In the course of its life in a building construction, even a well produced VIP panel will take up small amounts of air through the welding seams and pinholes in the laminate. This raises the internal pressure and above a certain value, the thermal resistance is lowered.

Within the project „HiPTI – High Performance Thermal Insulation“ of IEA/ECBCS Annex 39, numerous studies were conducted on the thermal bridging and aging effects. During the course of the research project, the quality of the panels and particularly the laminates has increased. The results of these studies led to the recommendation for the presently available VIP with metallized laminated films, normal panel size (e.g. 50 x 100 cm^2) and correct installation in the construction, to add to the thermal conductivity an allowance of 0.001 to 0.002 W/(m·K) for thermal bridging and a further 0.001 to 0.002 W/(m·K) for aging (pressure rise). Depending on the panel size, thickness and placement, one calculates a thermal conductivity of 0.006 to 0.008 W/(m·K) for normal applications. This does not, of course, take into account constructive thermal bridges such as joints of the VIP insulation to walls and ceilings.

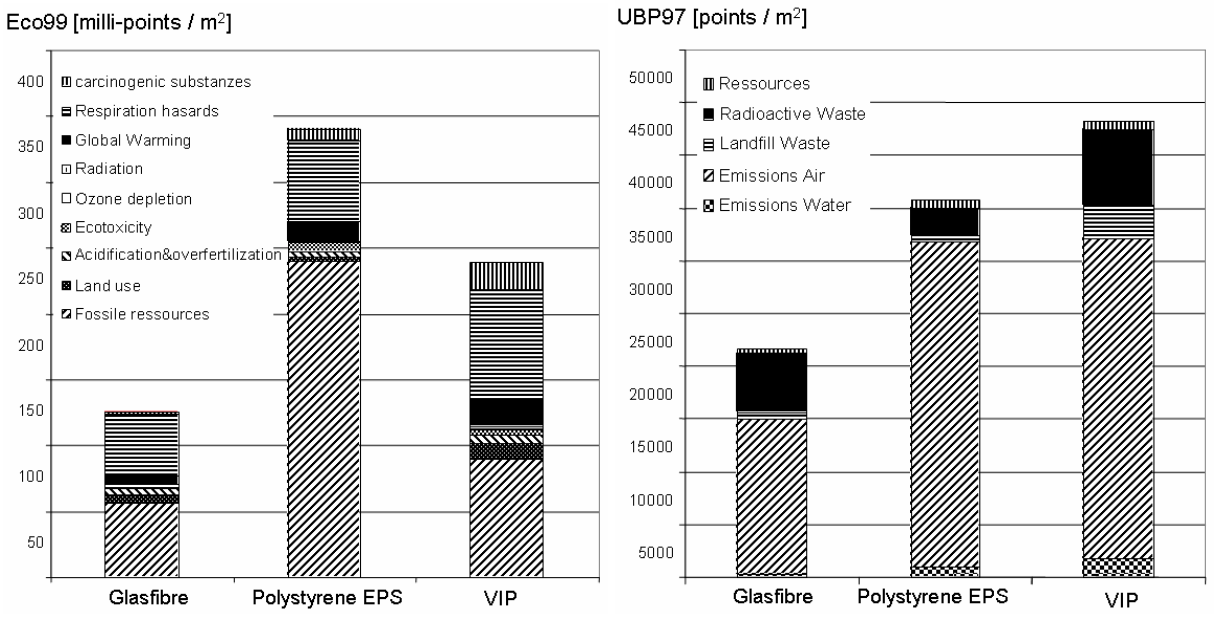
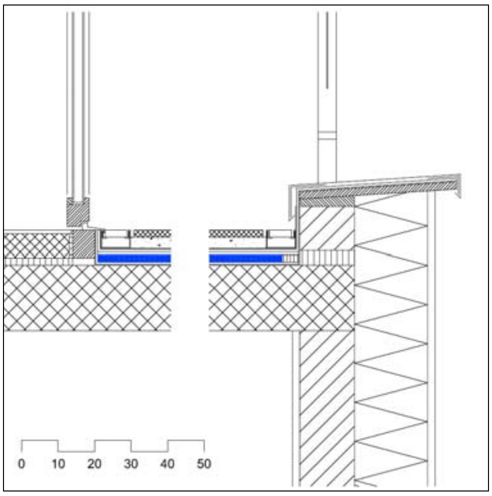


Figure 1: Comparison of the categories of effects for the insulating materials glass wool, polystyrene EPS and VIP (left Eco-indicator 99, right UPB 97)

The use of new materials always poses the question of the long-term ecological effects. Within the scope of this project, a detailed life cycle analysis (LCA) was performed (Figure 1). 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 standpoint.

3 VIP’s in practical use

VIP are today mainly installed directly in the construction on site. By far the commonest use in Switzerland is the insulation of flat roof terraces with VIP (Figure 2). This provides a simple method of avoiding unpleasantly high steps between the interior and the terrace. In the planning process an exact laying plan for the VIP must be prepared. If necessary, the use of conventional insulation at the edges can be minimized with individually made-to-fit pieces. During laying on site one must make sure that the VIP is covered by a protective layer as soon as possible to avoid damage by falling objects and incautious walking. Furthermore one should pay attention to dry materials and dry weather. Already small amounts of water (rain drops), because of sealing on all sides, can lead to a permanently increased vapour pressure in the entire construction, which can even be detrimental to the insulation properties of the VIP.



Floor structure

garden tiles	20 mm
flint (draining)	30 mm
protection mat	5 mm
bitumen sealing	2 mm
rubber meal mat VIP	8 mm
PE foam mat	20 mm
vapour barrier	5 mm
concrete ceiling	0.3 mm
	200 mm

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

A wide range of constructions for exterior and interior insulation of façades were developed and built (composite systems, jamb crossbar constructions with sandwich panels, curtain wall constructions, prefabricated concrete elements etc.). The following examples demonstrate the potential of vacuum insulation for slim and space saving façade constructions.

Figure 3: View of the apartment and office block in Munich/Germany with a VIP composite system. Mounting the polyurethane foam panels onto the ceiling. Monitoring the gas pressure within the VIP with a portable device. (Architect: Martin Pool / VIP-construction: energie-tib)

The façade of an apartment and office block in Munich/Germany was equipped with a VIP composite system. The vacuum insulation panels were fixed to the concrete walls with adhesive. The VIP were installed between vertical laths of recycled polyurethane fixed with wall plugs. The polyurethane foam panels onto which the plaster was applied are securely attached to these laths (Figure 3).

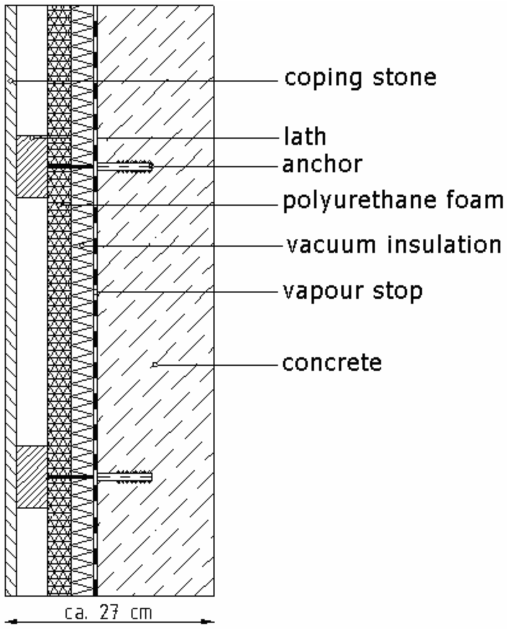


Figure 4: Horizontal section of the prefabricated wall element. An average U-value of 0.15 W/(m²·K) is achieved with a total thickness of 27 cm. View of a prefabricated wall element with VIP. (Architect: weinbrenner.single / Construction: Hangleiter GmbH & Co KG)

For an office building with an apartment in Ravensburg/Germany prefabricated concrete elements with VIP were developed (Figure 4). VIP are laid onto fresh cement and held in place with a few anchors. Due to the special design of the elements, VIP can be replaced at any time, if necessary. The elements provide a very slim construction with few thermal bridges (U-value 0.15 W/(m²•K)) and due to the fact that they are prefabricated, installation is facilitated and a high degree of quality assured.

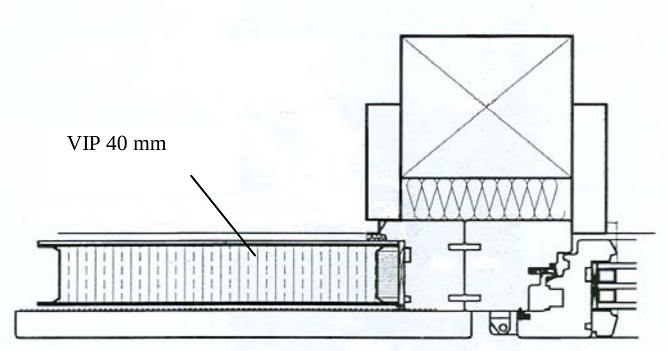


Figure 5: Vacuum insulation panels in the form of stainless steel cases used as outside wall elements on single-family terrace houses in Binningen / Switzerland. Left: Horizontal section through the construction. Right: Installation of the VIP. (Architect: Feiner Pestalozzi / VIP-construction: Häring AG)

On five terraced houses in Binningen/Switzerland VIP one storey high (ca. 2.60 x 1.60 m^2) were installed in a wooden window frame construction. Apart from laminate-enveloped VIP, these are vacuum building panels consisting of evacuated stainless steel cases, also with a core of fumed silica (Figure 5). The panels can be manufactured in large sizes (up to three by eight metres) and are extremely vacuum-tight and robust. In this project for aesthetic reasons, the panels were provided with an additional metal facing on the outside. On the inside a wooden covering layer was installed. Repair of the VIP at a later date is possible by welding the damaged location and subsequent re-evacuation.

Although the processing of VIP under controlled conditions by specially trained personnel in a factory would be highly desirable, only a few prefabricated products and systems are available for the building sector. There are, however, signs that more component and system manufacturers are becoming involved in the development of such products. It can therefore be expected that in the foreseeable future, a wide selection of products such as floor heating systems, outside doors and wall elements with VIP will be offered.

Figure 6 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 design of the construction, one can dispense with lathing between the VIP, which further reduces the heat losses.

Figure 6: Prefabrication, installation and view of the finished dormer window for the renovation of an old building in Zurich / Switzerland. (Architect: Viridén + Partner AG)

4 Use of VIP – Recommendations

VIP is more than a new material – it must rather be regarded as a system, one of consider-able complexity and sensitivity. It is therefore important that 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). In whatever way VIP are used in the construction branch, those responsible should make sure that during the planning and building process, no one handles VIP without having sufficient knowledge of its properties. Postal parcels with sensitive contents are marked with a „Handle with care“ label because they pass through many hands. VIP should, as a rule, fulfil their function in buildings over decades. Wherever they are not installed absolutely safe from damage, tenants, owners and renovation workers should also be warned with a label of the sensitive contents of building components. We thus recommend VIP manufacturers and suppliers to develop a warning label (Figure 7).

VIP must be handled with care and suitable protective measures and tools employed (protective mats, felt shoes, etc.). In addition, the most important recommendations for handling VIP both in the factory on fabrication of components and systems, and also for direct installation on site:

In order to minimize the edge effects of the VIP:

- Select panels that are as square and large as possible (min. 0.5 x 0.5 m^2)

- If the envelope of the panel is made of aluminium foil (only rarely nowadays), lay the panels in a double layer, overlapping by at least 5 cm (which, however, is expensive).

Figure 7: Draft sketch for an adhesive warning label to mark VIP panels and building components containing VIP.

VIP must be well protected from mechanical damage. This applies equally to functional loading (e.g. from the floor), inadvertent loading (e.g. dilatation) and subsequent manipulations (e.g. nailing).

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. The joints and edges are usually sealed with a special adhesive aluminium tape, which assures tightness but is relatively brittle.

The possibility of individual panels or entire areas failing should - at least to date - be included as a risk in the planning and execution. A strategy would be desirable that would aim at being able to replace the VIP in case of failure. This implies two things that in our experience to date are not usually paid attention to:

- The VIP should be embedded in the construction such that they can be replaced without undue effort in preparation or as a result (e.g. mechanically fixed covers).
- Installation of the VIP in such a way that inspection of their correct functioning can be made, particularly with infrared thermography. As a rule this is impossible if on both sides, either well conducting, massive covers (e.g. concrete) or back-ventilated constructions are employed (provided that the latter cannot be removed relatively simply for checking the VIP).

As a rule, one has limited oneself up to now to mitigating the effects of failure, so that a deterioration in the U-value can be accepted and it is assured that on loss of vacuum, there is no risk of loss of comfort or of condensation

5. Reference

[Binz 2005] ***Vacuum Insulation in the Building Sector - Systems and Applications***, Binz, A. et al (2005), final report of the research project IEA/ECBCS Annex 39 “HiPTI-High Performance Thermal Insulation” Subtask B.