VACUUM INSULATED PANELS IN BUILDING APPLICATIONS

R. Bundi; K. Ghazi Wakili; Th. Frank

Laboratory for Applied Physics in Building
Swiss Federal Laboratories for Materials Testing & Research (EMPA)
Ueberlandstrasse 129, CH-8600 Duebendorf, Switzerland

ABSTRACT

Vacuum insulated panels (VIP) with fumed silica core enveloped in a polymer barrier with metal layers, are investigated with respect to their thermal performance. The effective thermal conductivity of the panels alone and the temperature and heat flux distribution of two facade panels with VIP's inside are presented. The application of VIP's in retrofitting of old buildings will be discussed by means of a construction example.

ZUSAMMENFASSUNG

Vakuum Isolationspaneele (VIP) mit pyrogener Kieselsäure als Kernmaterial verpackt in einer mehrschichtigen Polymer-Metall Folie werden auf ihr thermisches Verhalten hin geprüft. Die effektive Wärmeleitfähigkeit der Paneele an sich sowie die Temperatur- und Wärmestromverteilung von zwei Fassadenpanelen mit integrierten VIP's werden dargestellt. Der Einsatz von VIP's bei Nachträglicher Dämmung von Altbauten wird anhand eines Konstruktionsdetails besprochen.

INTRODUCTION

Vacuum insulated panels consisting of a fumed silica core [1] and a multilayer metallized polymer envelope are currently investigated with respect to their thermal and ageing qualities within a project of the International Energy Agency (IEA) ANNEX 39 „ High Performance Thermal Insulation in Building and Building Systems". The present paper deals only with the thermal aspect of VIP's. The prediction model for ageing of VIP's will be presented by S. Brunner (EMPA) during the poster session of this conference [2] . In a first step the influence of the high conducting metal layer in the barrier envelope on the effective thermal conductivity of the VIP will be quantified. Second, two different facade panels with integrated VIPs are analysed to show the influence of the materials used for the assembly. In a third step the application of VIP's in retrofitting will be presented.

METHOD

For all three steps numerical analysis was applied by means of the TRISCO program [3]. This software allows 2- and 3-dimensional steady state heat transfer calculations in objects described in a rectangular grid using the energy balance technique. In the analysis all material layers were considered with their real thickness and thermal conductivity. This applies even to the aluminium layers with a thickness in the nanometer range (1 nm = 10^{-9}m).

THE VIP ITSELF

The effective thermal conductivity of the whole VIP is affected by the thickness of aluminium used in the barrier envelope. This is due to large difference between the thermal conductivity of aluminium and that of the evacuated fumed silica core.

In the European market, there are several producers of VIP's using different types of barrier envelopes. In all products aluminium layers are used as barrier material. The thickness of these layers vary from 8 microns (laminated aluminium foil) down to 90 nm in case of multilayer metalized foils. For our study we chose VIPs from 3 different suppliers with 90, 300 and 8000 nm aluminium respectively.

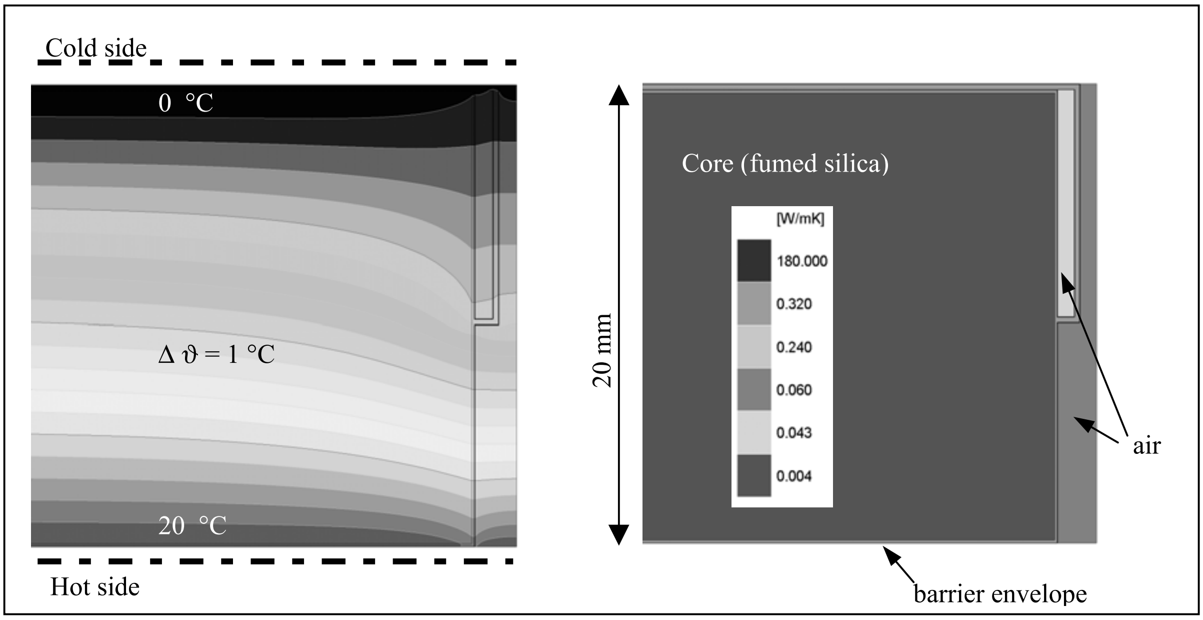

Figure 1 : Modelled half of a cross-section through a joint of two adjacent VIPs. Left isothermal, right material representation

Figure 1 shows the modelled half of a cross-section through a joint of two adjacent VIPs. Because of wrinkles on the envelope and the uneven edge of the panels themselves, there are always air cavities in a VIP joint, which have to be considered in the calculations.

Due to the fact that the aluminium layer surrounds the core completely, there is an additional heat loss through the edge of a VIP. This can be represented by a linear thermal transmittance (ψ). The effective thermal conductivity of the whole VIP depends strongly on ψ and the perimeter to area ratio. This means that small and narrow panel dimensions should be avoided. A summary of the measured results for a quadratic panel size of 1m x 1m is given in Table 1. Theses measurements are made in a guarded hot plate device with additional rubber layer to avoid thermal short circuiting in metering area caused by the envelope.

VIP	d [m]	λ_{cop} [W/mK]	ψ [W/mK]	λ_{eff} [W/mK]
Type A 90 nm Aluimium	0.020	4.14×10^{-3}	6.96×10^{-3}	4.70×10^{-3}
Type B 300 nm Aluimium	0.020	3.91×10^{-3}	9.19×10^{-3}	4.65×10^{-3}
Type C 8000 nm Aluimium	0.018	3.95×10^{-3}	52.44×10^{-3}	7.73×10^{-3}

Table 1 Effective thermal conductivity of VIP's for a quadratic size of 1m × 1m

These measured results were used to validate our numerical model described above. The comparison of measurement and calculations shows a good correspondence. Detailed information to this topic can be found in [4] and [5].

VIP USED IN FACADE PANELS

Facade panel is a good example for VIP applications in buildings. The barrier envelope of a VIP is easily damaged, i.e. the vacuum gets lost, and the VIP looses its super insulating characteristic. Therefore, it is advisable to deliver the VIP in a protecting component. This usually does not need additional effort because facade panels are assembled in the workshop before getting to the building site anyhow.

The need for thin panels with a good thermal resistance is growing especially for facade construction where the transparent and non transparent elements have to be of the same thickness.

In the following two types of facade panels are shown. Their U-Value (thermal transmittance coefficient) was calculated with both, a 3D and a weighted 1D calculation. The latter neglects the heat fluxes perpendicular to the heat gradient.

Local thermal bridges are frequent in facade construction (screws, local metal sheets, etc.). Their influence is larger the better their surrounding is thermally insulated. This is the case when VIPs are used.

If a plane element with a high thermal conductivity is connected to such a thermal bridge, it acts as a heat collector and enforces the heat losses through it. This collector characteristic can only be calculated in 2D or 3D calculations. For the following panels, the cladding sheet acts as a collector and the spacer going around the VIP as a thermal bridge.

Panel Type 1 stands for the most common type of facade panels where the insulation material is sandwiched between two metal sheets and the spacer is approx. 30mm thick.

Type 2 is a simplified model for a special panel construction where a thin spacer is approximated by an aluminium sheet of 1mm.

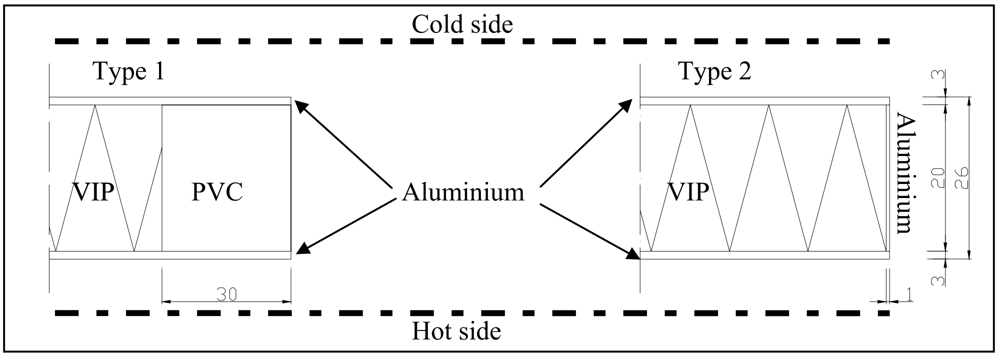

Figure 2 : cross-sections through the panel edge. Panelsize:1 x 1 m2

Material	Aluminium	PVC	VIP core
Thermal conduct. λ [W / mK]	160	0.2	0.005

Table 2 : cross-sections through the panel edge. Panelsize:1 x 1 m2

	U value		
	3-dimensional	1-dimensional weighted	Difference
	[W/m^{2}K]	[W/m^{2}K]	
Type 1	1.07	0.64	40 %
Type 2	3.27	0.26	92 %

Table 3 U-Values of the two types of panels

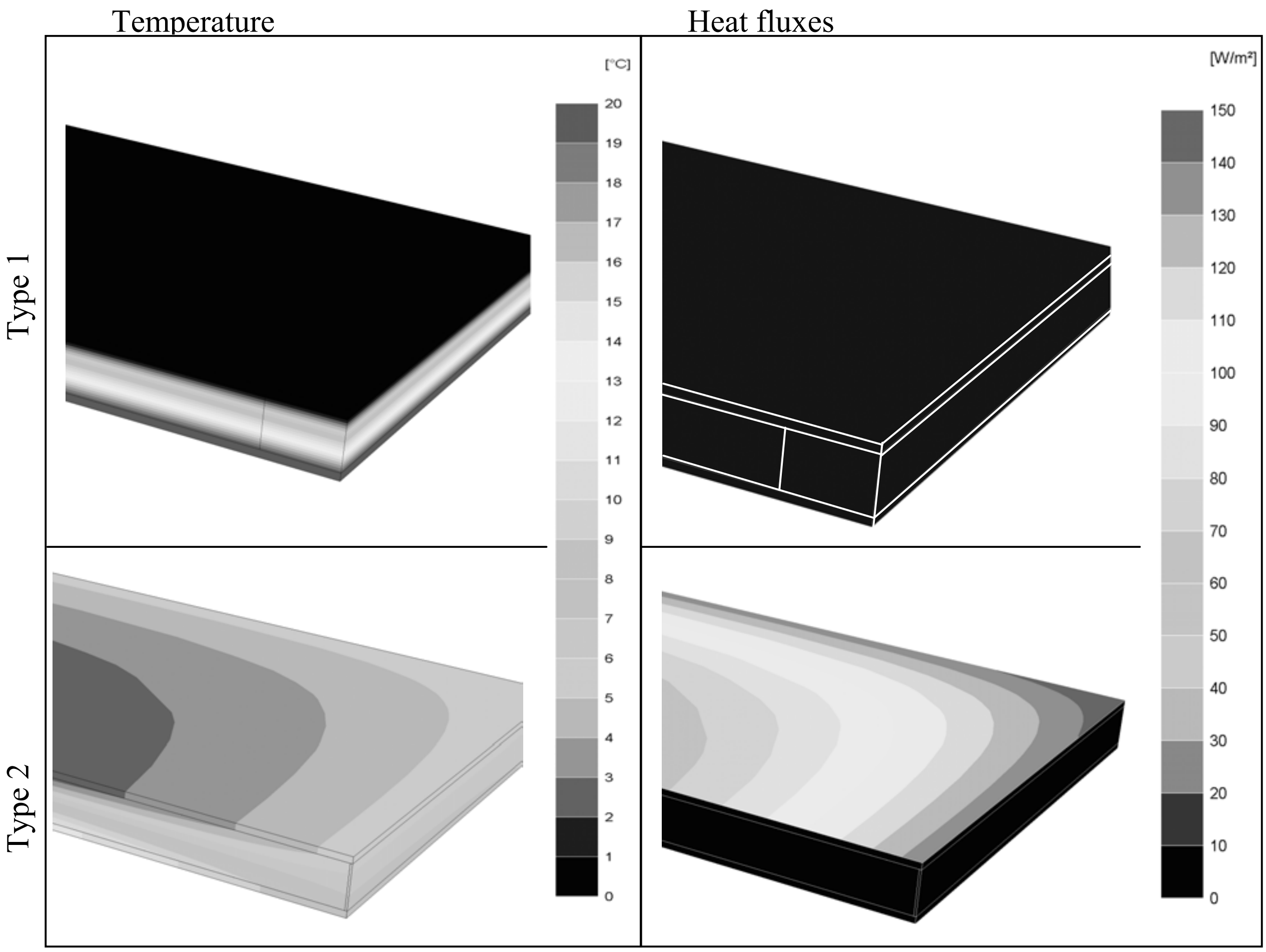

Figure 3 Temperature- an heat flux distribution. Shown is a 3 dimensional cross section

VIP USED IN RETROFITTING

Installing additional heat insulation in buildings has in the most cases the disadvantage of a great loss of floor space. Therefore, VIPs are of interest for retrofitting. An additional thickness of a few centimetres allows to reach good insulation values. The following example shows a retrofitting of an uninsulated building, where an exterior insulation was impossible because of the monument conservation laws.

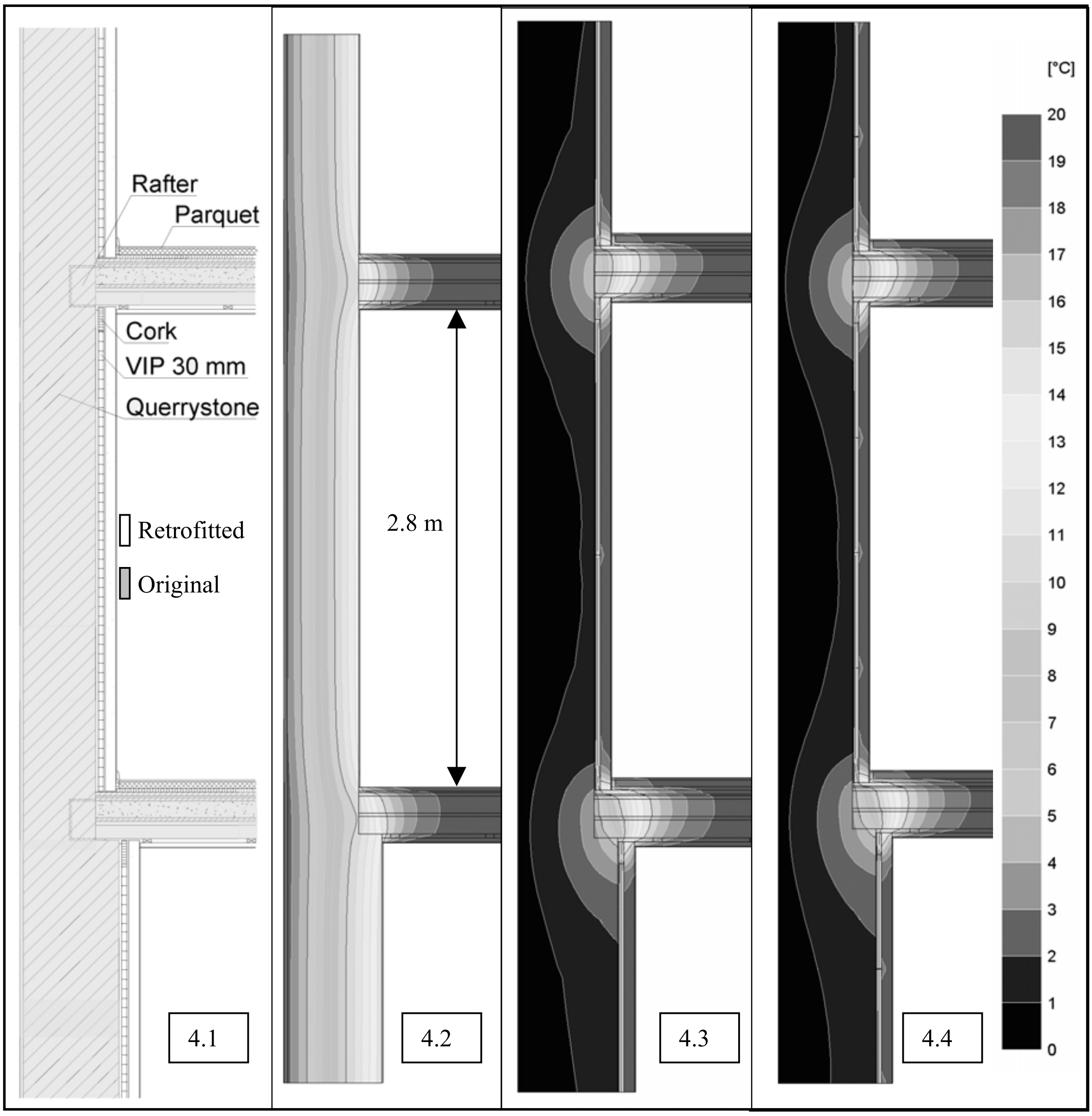

Figure 4

4.1	*Vertical cross-section trough the wall.*
4.2	*Isothermal view of the cross-section in the original condition*
4.3	*Isothermal view of the cross-section in the retrofitted condition. The used VIP format is 0.6 x 1.34* m^2 *(2 per height between floors)*
4.4	*Isothermal view of the cross-section in the retrofitted condition. The used VIP format is 0.6 x 0.67* m^2 *(4 per height between floors)*

	Total heat fluxes
	[W] (Δ T = 20 K)
Original construction (4.2)	161.00
Retrofitted construction (4.2)	11.40
Retrofitted construction (4.3)	11.64
Retrofitted construction neglecting aluminium in VIP-Envelope	10.81

Table 4 Total energy losses through detail shown in Figure 4

The values in table 4 show the huge potential of VIP in this sector of civil engineering. Details as the joint of the VIPs and the connection to the surrounding components need to be solved separately and carefully. On these sites low surface temperatures and air leakages can cause condensation damages.

ACKNOWLEDGMENTS

The present work got financial support from the Swiss Federal Office of Energy.

REFERENCES

1. Caps, R., Heinemann, U., Ehrmanntraut, M., Fricke, J. : Evacuated insulation panels filled with pyrogenic silica powders: properties and applications. High Temperatures-High pressures, 33, 151-156, 2001.
2. Brunner S., et al: Development of service life prediction models for vacuum insulation panels (VIP) (Poster session 6, New construction materials and systems)
3. TRISCO & KOBRU86: Computer program to calculate 3D & 2D steady-state heat transfer in objects described in a rectangular grid using the energy balance technique.
4. Ghazi Wakili, K., Bundi, R., Binder, B. : Effective thermal conductivity of vacuum insulation panels VIP used in building constructions, paper submitted to Building Research and Information (2003).
5. Simmler, H. : Measurements of physical properties of VIP. High Performance Insulation Systems, Vacuum Insulated Products (VIP), Proceedings of the international conference and workshop, Ed. Zimmermann, M. and Bertschinger, H., Centre for Energy and Sustainability in Buildings, EMPA Duebnendorf, Switzerland, 2001.