Scientific analysis of an internal insulation system based on prefabricated vacuum panel composite boards

Short report

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Aim and execution of the research project

Object of this research project are analysis on a marketable integral internal insulation system based on composite boards with vacuum insulation panels including the corresponding planning and application advices. In order to achieve the purpose, the project has been divided in different work steps.

Work step 1: Development of a thermal-hygric model by an existent software for the simulation of the humidity behaviour of a vacuum internal insulation system on different exterior walls of old buildings and under different dampness-technical edge conditions over several years.

From this have been derived the preconditions regarding the building physics that are appropriate to the application of a vacuum internal insulation system.

Work step 2: Analysis of prototype composite boards in the laboratory construction for the testing of properties.
The aim of this work step is the acknowledgment of the properties expected by the simulation and the recognition of potential existing weak points and risks.

Work step 3: Planning and execution of the modernisation of at least two sample flats of the German existing old buildings by using the system tested in laboratory. Thereby the specific connection details have been elaborated and documented and practical experience has been gained by the realization of the internal insulation.

Work step 4: For the evaluation of the simulation data temperatures, humidity and heat flows have been carried out on at least three measurement points of the internal insulation construction (including the old walls), in order to get a continuous collection of the measurement data.

Furthermore in total 76 suitable constructions and detail solutions have been analysed for a multitude of building types with different building ages.

Part A Basic information for the internal insulation

The application of conventional internal insulation systems in old buildings is limited until now on the properties that have enough space for these internal systems. The insulation composite elements developed and practice-tested by the company VARIOTEC allow a space-saving and furthermore highly efficient internal insulation system as an alternative for external insulations.

In principle the building physical basics and the moisture sources on external walls as e.g. driving rain, condensate water and increasing basic moisture as well as the initiating building moisture have to be extremely exactly taken into consideration for these internal insulation methods.

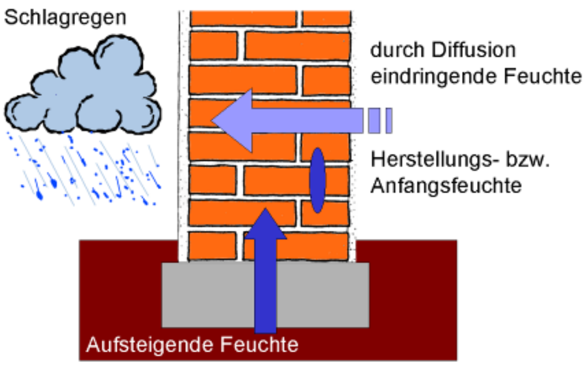

Figure 1: moisture sources on external walls (rain water, condensation water, increasing basic moisture and initiating building moisture)

Particularities concerning internal vacuum insulation

VIP elements are produced as a sandwich module with adequate covering layer materials, in order to protect the high barrier foil of perforation.
The butt joints of the elements are sealed by an elastic, fleece-covered butyl adhesive tape. By this construction method a large-scale panel can be produced as a polyfunctional unit consisting of thermal insulation (VIP) and vapour barrier (thin aluminium sheet).

Such an internal insulation system is absolutely vapour diffusion-tight. All perforations, butt joints, edges and connections to the building structure have to be accurately sealed. In this way a protection from damp permeation into the internal insulation resp. into the external wall from the room air is guaranteed, whether by diffusion or by convective flow of the insulation elements. Therefore a drying of the wall on the internal surface is permanently excluded, as for every diffusion-tight internal insulation.
Therefore the safe protection from external damp permeation will take on great importance. As for every internal insulation, but to a greater extent for VIP insulation, a special importance is attached to thermal bridge effects.

Elements that connect to exterior walls are not changeable and only so a reduction of the thermal bridge losses caused for example by concomitant insulation can be obtained. A great importance is attached to an accurate detail formation of all element joints and perforations. Imperfections caused by defects in the construction, unknown joints in the existing construction or by damages during the service life cannot be excluded.
Therefore their influence has been analysed in this project.

Recommendations for the application of VIP internal insulation

The application of VIP internal insulation can be recommended for the following facades, if it is not possible to apply external insulation:

- All facades on which water repellent plaster and paint can be applied
- Clinker facades with refurbished joints and tested water repellent treatment
- Facades with facing or facing brickwork

Installation of VIP internal insulation elements

The large-scale VIP panels are fixed in the external wall by thermal bridge reduced polyamide or glass fiber reinforced plastic screws.
By the use of these materials with a low thermal conductivity the requirement for the avoidance of thermal bridges is fulfilled.

Vacuum insulation panels are produced with low tolerances for the evenness and are as rigid boards not able to equalise unevennesses on the surface. Cavities between the insulation level and the existing external wall are unrequested and have to be avoided by an elastic intermediate layer.

Part B Laboratory test

The laboratory tests on an internal insulation system based on composite boards with vacuum insulation panels had the aim to create the basics for the corresponding planning and application advices, so that the realised system presents a flawless solution from the building practice and building physical point of view for the modernisation of old buildings.

When carrying out the laboratory tests it was not the point to reproduce the field test on the test bench, but rather to prove the validity of the simulation model and to compare it with the real material data.

Since hygric processes require an appreciably longer period of time than heat transfer processes, it has been worked with thin material thicknesses in the experimental setup. When the field measurement has been carried out, concrete has been applied as a representative material for the external wall of an old building.

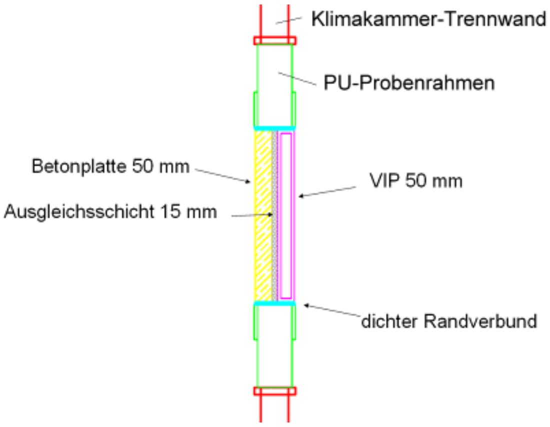

Fig. 2 Layer construction of the test specimen **Fig. 3 Layer construction and positions of sensors**

The tests in the laboratory have been simulated in the difference climate chamber. The test specimens have been equipped with a combined temperature / humidity sensor. Furthermore the heat flow through the test specimen has been measured by a heat flux plate.

Moisturisation experiment for the simulation of driving rain

The water absorption by driving rain on an external wall is of great importance for a vacuum internal insulation. In order to be able to simulate this water absorption under defined conditions in the laboratory test, preliminary tests have been carried out on a concrete board.
From a quantity of water of 61 g sprinkled by an aerosol can 53 g have been absorbed by the concrete sample according to the results of the preliminary tests.
By means of the coupled thermal/hygric simulation the run of the temperatures and of the heat flows as well as of the Aw-value in the layer construction of the test specimen could be calculated.
Apart from some exceptions the compliance is satisfactory especially in areas with low temperatures, the impacts caused by driving rain (simulated by defined spray tests in the laboratory test) are realistically reproduced by the simulation model, too.

Part C + D Construction details and calculations of thermal bridges according to classification in building ages

In the framework of the research project a systematic list of relevant details for the application of vacuum internal insulation has been prepared. Therefore characteristic constructions have been analysed depending on the classification in different building ages. Versatile details have been defined and the corresponding detail drawings have been developed (building periods from 1870 – 1985).

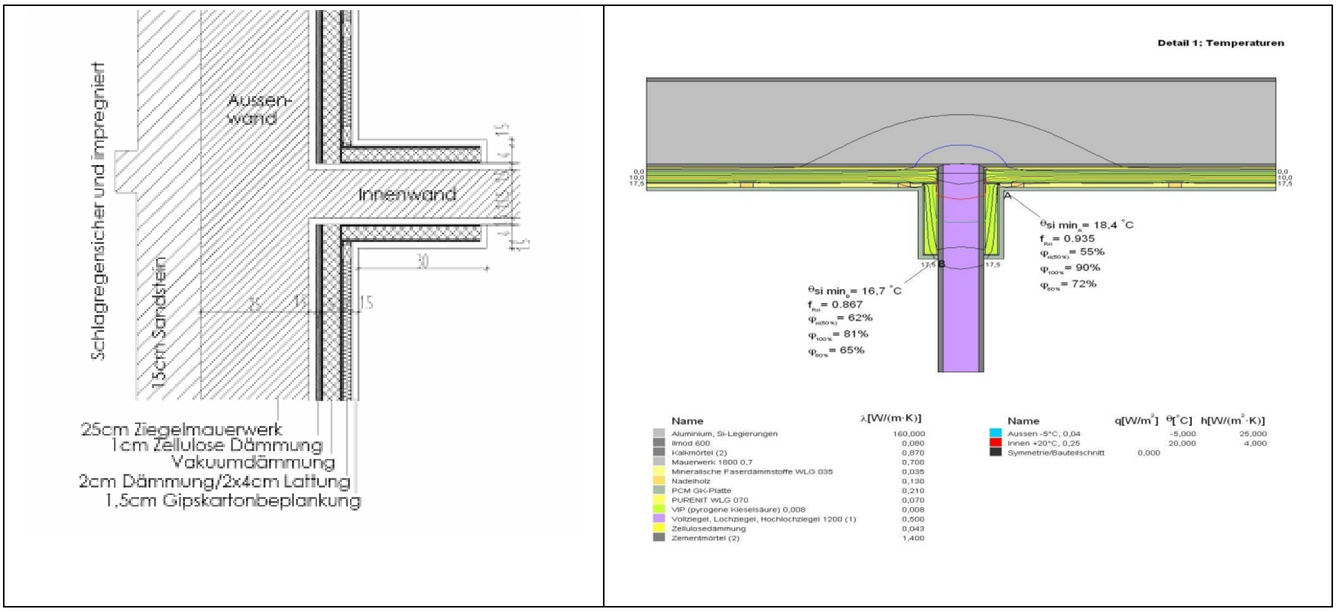

Fig. 4 Detail construction of an external wall from 1870 – 1920

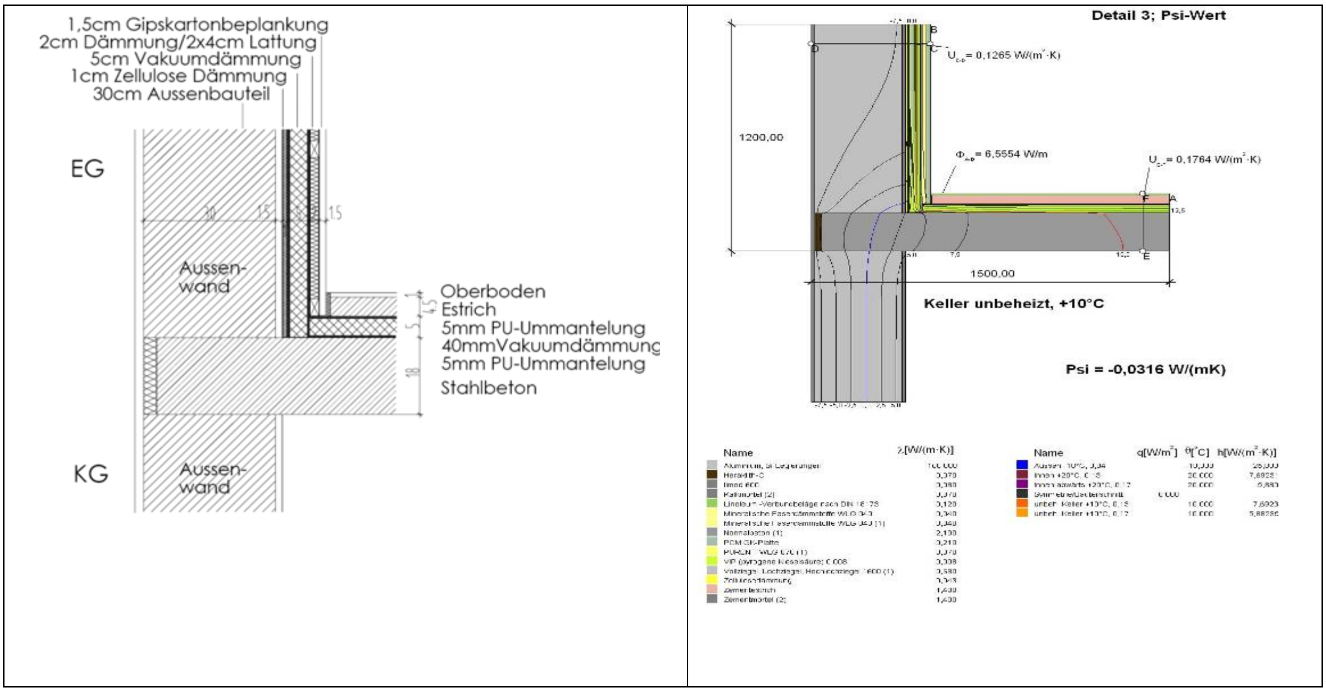

Fig. 5 Detail constructions of the foundation from 1945 – 1960 basement/ground floor

Part E Pilot project Neuwied

The building of the residential home of the hospital in Neuwied served as the first object for a field test of the internal insulation construction with vacuum insulation panels that had been planned before. The building that had been put up in an armoured concrete construction in about 1960 has been completely energetically refurbished. In doing so a composite insulation system has been applied on three main facades. For the fourth facade (Northeast) it could not be realised an external insulation because of the close surrounding property. An internal insulation has been taken into considеartion.

Construction

Floor to ceiling panels have been applied for the pilot project Neuwied. For this purpose a manufacturing plan and a lay-out drawing have been developed according to accurate measurements. These corresponded to the requirement of a possible low quantity of different sizes of VIP elements due to the production process. Then the single elements have been put together to 8 large-scale panels for the wall surfaces according to the layer construction showed in figure 2.

Firstly a 30 mm thick equalising layer of hemp fibre insulating mats has been glued on the 180 mm thick external wall of armoured concrete, in order to level unevennesses in that the rigid VIP panels could not fit and with the aim to influence in a positive way the moisture content in the interspace.

Fig. 6 Hemp fibre insulating mats as an equalising layer

Fig. 7 Positioned panels on the wall surface

Measurement concept

In order to create the preconditions for the determination of the real behaviour of the construction, sensors have been installed in the center of the insulated wall for all important parameters of the thermal and hygric behaviour. Furthermore the surface temperature is measured on the critical point of the transition of the concomitant insulation to the construction. All sensors will be recorded by a central data collection system (ALMEMO Datenlogger 2890-9, Co. Ahlborn MRT) in intervals each minute (average values). The measurement channels are detailed in the following table:

No.	Parameter	Measurement point	Short designation	Type
1	Impact of driving rain on external wall	Outside exterior wall	Rain1	THIES 5.4103.20.041
2	Temperature on the external wall	30mm behind exterior surface of exterior wall	Ex. wall1 t	E+E 06
3	Relative humidity of the external wall	30mm behind exterior surface of exterior wall	Ex. wall rh	E+E 06
4	Heat flow	Interior surface of external wall	Heat surf.	Phymeas T7
5	Temperature of the equalising layer	Interior surface of external wall	Equal.1 T	E+E 06
6	Relative humidity of the equalising layer	Interior surface of external wall	Equal.1 rF	E+E 06
7	Humid equalising layer	Interior surface of external wall	Wood1	Ahlborn MRT FHA636MF
8	Surface temperature	Interior surface of VIP	Surf. VIP1	Pt100 Foil sensor Ahlborn MRT FP0685
9	Surface temperature	Interior surface facing	Surf. GK1	Pt100 1/10 DIN B
10	Surface temperature	Transition concomitant insulation / construction	Surf. VIP2	Pt100 Foil sensor Ahlborn MRT FP0685
11	Temperature of the room air	Ceiling area	Rooml1 T	E+E 06
12	Humidity of the room air	Ceiling area	Rooml1 rF	E+E 06

Summary of the pilot project Neuwied

The analysis of the climate data in place and of the existing weather data for the evaluation period from 21st of August 2007 until 23rd of April 2010 indicates average conditions during the measure monitoring. The internal insulated wall is wind-averted and is classified into a driving rain impact on the limits of the stress groups I and II according to DIN 4108-3.
The measured values lie throughout in an uncritical area. The recognizable trends indicate a durable damage-free function and comply with the values that had been determined by numeric simulation calculations in advance. The results show that thermal bridges can be reduced by using concomitant insulation, that is to say that damages in construction work due to moisture can be reliably avoided.

Moisture relationship in the construction of the component

Apart from the moisture conditions on the surfaces of the components considered before, the moisture within the component and its long-term development for the functionality of the construction is of great importance. Therefore it has been continuously determined in different layers of the component.

At the measuring points the moisture is always below the critical threshold of 80% relative moisture (corresponding to an a_w -value of 0,8).

The trend shows a moisture increase diminishing by and by. It is foreseeable by a comparable extrapolation as with the simulation results that a balance is achieved with a mean value of 70% after approximately four until five further years. This complies with the results of the simulation calculation discussed before.

Description of the project Springe-Eldagsen

In the framework of a project for internal insulation in the energy and environment center in Springe-Eldagsen in the region of the Deister various rooms have been equipped with different materials for internal insulation systems. An office room has been equipped with QASA vacuum internal insulation as well as with passive house windows.

The vacuum internal insulation has been mounted without intermediate layer of hemp. In comparison to the project Neuwied the mounting has been carried out only by gluing with PU building adhesive. Unevennesses in the surfaces had to be equalised, to be prepared smoothly and a tearing resistance test of the glue had to be carried out.

Conclusion:

The fixation of the internal insulation panels without mechanical fixing proved to be difficult, as the substrate and the gluing conditions have to be ideal. The further development of the QASA elements for internal insulation is based on a mechanical fixing. This type of mounting can be considered unproblematic and is proposed to be carried out.

Summary of the results

The internal VIP insulation is an absolutely air tight system that stops the vapour diffusion from interior to exterior.
The infiltrated moisture to the interior does not evaporate anymore. A mechanical air ventilation system and an exhaust ventilation with heat recovery has to be planned depending upon property size.

External wall: Increasing capillary moisture

A basic precondition for the application of internal insulation is that the external wall that has to be insulated does not create problems regarding the increasing of capillary moisture.

A continuous moisture transport from the cellar, plinth or foundation area leads to a superelevated humidity that would inevitably entail damages on the exterior and interior side of the brickwork. Therefore it is necessary to check exactly the moisture of the brickwork and its causes and to carry out a secure sealing against the increasing moisture.

External wall: Protection from driving rain
The moisture entering in the construction of an external wall by driving rain may lead to essential damages in the construction when internal insulation has been applied. Therefore it is of great importance to check the facade during the planning concerning this matter.
Half-timbered work poses problems concerning the situation of driving rain. That is the reason why the use of vacuum internal insulation is not recommended in connection with such constructions. Even with a meticulous execution during the refurbishment water can entry in the area of the joints between beam and infill masonry or within the beams due to movements between the different construction parts.
Exposed masonry is possible in numerous forms of construction and has to be individually evaluated. **Solid brickwork** was often used in connection with **faced brickwork** in the Wilhelminian style. For such constructions the conditions of the brickwork joints as well as the brickwork itself concerning its humidity absorption from driving rain have to be checked. In general a water-repellent treatment is necessary, whereby a very exact analysis of the required boundary conditions has to be carried out. The same situation is given for constructions with facing tiles.

Renders and coatings have a very good driving rain protection. Requirements for the driving rain protection have to be taken into consideration according to DIN 4108 and 18550 [DIN 4108-3 and DIN 18550 part 1]. For buildings of the stress group II water-inhibiting renders have at least to be used, for stress group III water-repellent renders have to be used. Therefore the coat of water-repellent, hydrophobic, but permeable external renders is required for the energetic refurbishment in regions with an elevate driving rain rate.
Internal insulation itself often shows leaks on the lower, upper and lateral connections to the connecting construction parts. Therefore it is of great importance that the internal insulation is applied on the whole surface area toward the external wall and without air gaps. This can be made by adhesives on the whole surface or by a deformable insulation material. This avoids the circulation of room air behind the internal insulation and the subsequent condensation of convection humidity in this cold area. By using a mechanical domestic ventilation there is a typical room air humidity of 40% until 30% in the relevant months January until March. In this way not only a good air room quality is guaranteed by the ventilation system, but also favourable boundary conditions are created for the use of internal insulation.

Summary and perspective

If the requirements for the application of vacuum internal insulation can be fulfilled, this form of insulation presents a good option for the energetic refurbishment of buildings. It improves the comfort and it provides an essential energy saving, if it is not possible to apply external insulation.
However all building physical influences have to be checked. Especially important parameters are the state and the moisture impact of the external wall that have to be taken into consideration by planners and manufacturers.
When analysing the projects it becomes clear that it is possible to achieve at least an energy saving by factor 4, in many cases also until factor 10, by using passive house components for almost all listed buildings.