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Testing a new method for VIP interior insulation for heritage buildings

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SUMMARY:
In old traditional buildings and even more in listed, historic buildings energetic refurbishment has to be planned thoroughly. For small rooms it may be of advantage to use thin and high efficient internal wall insulation systems like vacuum insulation panels (VIP). These systems have the best ratio of thickness to insulation, but they are also absolutely diffusion tight. This tightness makes a VIP system sensible to air leakage and air flows behind the panels. Also the mounting of interior insulation mostly affects disadvantageously the original surfaces and plasters. In case of valuable buildings this can lead to restrictions in retrofitting energy saving measures such as interior insulation.

A special focus is therefore put on reversible application in historic buildings. Refurbishments in old and valuable buildings should be carried out without or at least minimal damage to original surfaces and plasters compared to typical mounting systems. The presented mounting system reduces possible damage to original surfaces and plasters if a removal is necessary. The new system uses an additional layer between interior insulation and original surfaces to protect the surface and enable a save fixing.

The interior insulation system also has been tested experimentally to assess the influence to the original surface and possible damages to the plaster. Therefore the original surface was evaluated before mounting and after removal of the VIP interior insulation. The performance of the interior insulation was measured for one heating period.

This paper highlights the concepts of reversible application of the system. Also the measured data of the interior insulation and comparison of the simulation results with the measured data are shown.

1. Introduction

The use of internal wall insulation with vacuum insulation panels (VIP) provides a way for energetic building stock refurbishments, where special consideration to the external appearance of a building has to be taken into account and thin insulation thicknesses are required. The installation of VIP internal wall insulation in building stock often faces design problems and issues of removal and reversibility. Conventionally, fully adhered assemblies could not be dismantled without damage to the original surface.

1.1 Mounting of VIP

One problem of vapor-proof systems such as VIPs is a possible backside air flows between VIP-Panels and wall if there are cracks in the surface layer and cavities behind the Panels. These backside air flows can transport moisture and mould spores from the indoor air to the cold wall surface underneath the interior insulation and may lead to mould growth. To avoid backside air flows is full bonding of the panels to the wall, but this cannot always be guaranteed under the conditions of typical construction sites. The best method is to put the adhesive on both sides. But unevenness of old wall constructions, stiffness of panels and a thin use of adhesive makes failures possible. Not durable tight joints to adjacent building components in conjunction with cavities may lead to back side air flows.

Existing wall surfaces with loose plaster or painting could make an addition doweling of the panels necessary. Doweling of VIP panels is mostly only in additional edge zones made of e.g. polystyrene possible. This edge zones or dowel zones are additional thermal bridges.

1.2 Conservation of original surfaces and plaster in cultural heritage preservation

In the view of cultural heritage preservation a mostly comprehensive tradition of the historical building substance is aspired (Charta of Venice 1964). Also plasters or paint layers are informative about the ancient way of live and therefore worth to conserve. The use of typical adhesives based on cement with additional plastic additives may damage or destroy these near surface layers. Furthermore substances of the adhesive may migrate into deeper material layer. With this procedure an irreversible damage may occur to these layers. A good adhering system may destroy additionally the plaster if removed. One example of near surface layers in a historic building shows FIG 1. The exposed layers are documents of the historic of the building and give an impression of the taste of the epochs.

FIG 1: Exposed historic paint layers of a rectory oft he 16th century in Haimhausen in greater Munich (Picture: Klaus Klarner, conservator, Munich)

2. Experimental setup and measurements

The general aim of the project is the innovative application of an exemplary wall construction with vacuum insulation panels (VIPs) in combination with adhesive mats in the field of internal wall insulation of the building stock. New solutions and approaches should be developed, tested and demonstrated by the investigations. In conjunction with an adhesive mat as a separating layer, it is possible to design the internal wall insulation removable, as an important aspect of the reversibility for renovation and repair work in old buildings and historic preservation areas. The mats are pinned with only a few dowels to the wall. The adhesive mats are made of thin mesh with single-lined fleece. The fleece protects the original surface from the adhesive mortar used for fixing the VIPs to the wall, and thus enables an almost completely reversible attachment. Similarly, these mats enable a better adaptation of the dowel position given on the ground, which offers the possibility of placement in voids and thus help to protect valuable wall areas, e.g. with decorative historic paintings, and therefore can be beneficial for conservation reasons.

In this project, a combination of measurements in a case building object and computational simulation is performed, which serve to check a prototype wall construction for the economic and safe use of VIPs for existing buildings. In addition, a possible change of condition of the masonry surface will be examined and the measured data will be processed.

In a first step different adhesive matt systems that are available on the market, have been looked for and one of them is selected for use. Prior to installation, the construction was checked by calculation with the hygrothermal building simulation software WUFI® (Bichlmair et al 2012) developed by Fraunhofer IBP (Künzel 1994). The experiments took place in a building at the test site of the Fraunhofer IBP Holzkirchen. Here suitable test buildings, laboratories and workshops for the implementation of the project exist and also the required climate data for the site are known. FIG 2 shows the interior of the test building with test setup during mounting.

FIG 2. Interior view of the experimental building with the east and south walls with color swatches and some already mounted adhesive mat.

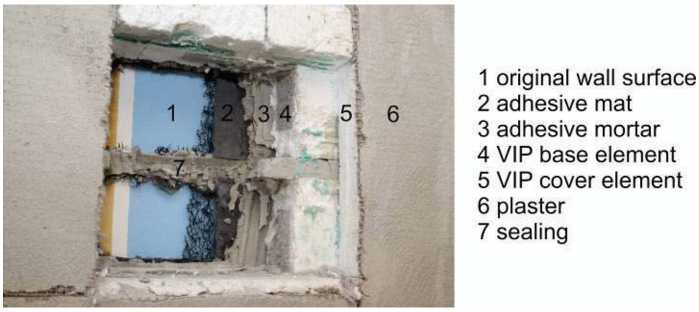

FIG 3. Component opening with layer indication of the interior insulation at the east wall.

If the interior insulation is not fixed accurate backside air flows with infiltrated indoor air may occur and then mold growth is possible. For specific measurements of backside air flow, the application of adhesive mat is suitable, since a defined layer of air of approximately 1 cm is present in the mesh (FIG 2 and 3). To achieve a higher level of security against backside air flow in the adhesive mat special horizontal seal joint was formed dividing the masonry in three sectors. To implement this sealing without thermal bridging a double layer VIP system with ca. 10 cm thickness were used for this purpose, originally developed for exterior insulation (Kolbe 2012). To assess the impact of the seal joint on the original wall surface different sealing methods were developed. Four different systems were selected therefrom and applied (Bichlmair et al 2012). In addition, some specific open joints as a gap with ca. 1 mm width were produced to the adjacent bottom and ceiling as a reference for not tight seals to adjacent building parts. The test setup for measuring backside air flows was planned and carried out (Bichlmair et al 2012) with the homogenous tracer gas emission method (NTVVS 118, 1997) due to good experiences with this method in historic buildings (Kilian et al

2011). The measuring period were too long, therefore the results cannot be used for interpretation. The further investigations on backside air flow were made computationally, based on the measured data for temperature and used test set up for the experiment.

The surface of the wall was painted with defined colors with different historical binders (FIG 2 and 4) to assess changes in consequence of the insulation (Bichlmair et al 2012). The color values were measured prior to mounting, using the standard method of CIELAB (EN ISO 11664, 2012). After removing the interior insulation, a further check on the original wall was made in order to assess the surface concerning degree of damage-freeness and change of the color values. The measured color lightness and color space are shown in FIG 4 in the right graph. There are only small deviations of the two measurements before mounting of the internal insulation and after removing almost 6 month later.

The left picture in FIG 4 shows the removed internal insulation with some leavings of the adhesive mat and adhesive. The first image shows almost complete conservation of the original surface. Only a small strip (rectangle 1) has high losses of substances. This strip was made as a reference sealing with adhesive directly mounted on the surface. Removing this directly applied adhesive led to the typical loss of the upper layers of the original wall, i.e. in this case the newly applied test colors.

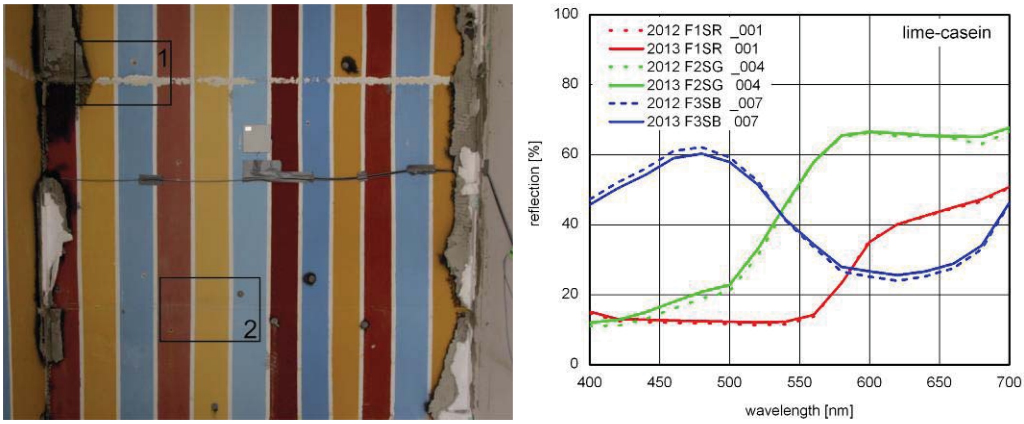

FIG 4. Left picture: South wall after removal of the interior insulation. For the areas of the numbered rectangles visual macro photos exist. Right graph: Color reflection on the binder system lime-casein on the south wall with the colors red, yellow and blue before and after application of interior insulation.

With examination of the surface visually mold growth could be observed on several areas. Within the different colors and binder systems no obvious pattern was recognizable. As mentioned several cracks were built for some test fields. The bottom fields with cracks had only a few and small mold spots, the fields at the ceiling had the most intense mold growth. The least mold growth but still visually recognizable has been observed in fields with no deliberately installed gaps in the middle of the wall.

To assess the effect of the internal insulation monitoring measurements were made with temperature sensors, relative humidity sensors and heat flow meters at the boundary layer and additionally with an infrared camera In addition, a combination of measurement and calculation is used for checking the developed component structure. In FIG 5 the north façade of the test building is shown with visual image and infrared (IR) image. The different thermal behavior is made visible with the IR image. In the center of the IR Image the insulated wall partition is shown with blue colors. The right wall partition remained with its original wall brick structure and is shown yellow-red colored. Two rectangular arranged measurement fields refer to the measured IR temperature within the insulated and untouched wall partition. The PT 100 temperature measurement is also located within the rectangular IR measurement field. One part is insulated with the internal insulation. The IR camera has an absolute accuracy of ± 1.5 °C and a thermal sensitivity of 0.07 K at 23 °C.

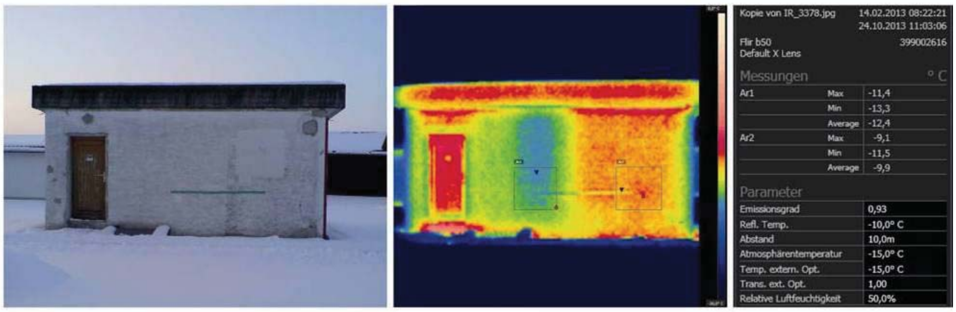

FIG 5. Exterior view of the north side of the test building with IR image, before sunrise, 14th Feb 2013.The temperature measured with IR correspond to the measurement with calibrated PT 100 temperature sensor within the accuracy of the measurements.

The left graph in FIG 6 shows the course of temperature of the insulated and not insulated wall partition from 01. 02. 2013 to 01.03. Comparing the both wall partitions the former original surface behind the interior insulation is cooling down almost to the level of the outside wall surface temperature. The temperature drops below 0 °C on the former original surface. The right graph in FIG 6 shows the temperature course of the insulated wall partition with additionally measured relative humidity on the former original wall surface. During the complete measuring period of almost 6 month the relative humidity was at 100 % RH, measured with a capacitive sensor with an accuracy of ± 2% RH and ±0.3 °C. The PT 100 temperature sensor was calibrated to ± 0.1 K. The temperature sensor of the humidity sensor was checked with an additional PT 100 sensor at the same interstitial layer whereas the PT 100 was fixed on the original wall surface. The humidity sensor measured the air in the small air cavity within the adhesive mat.

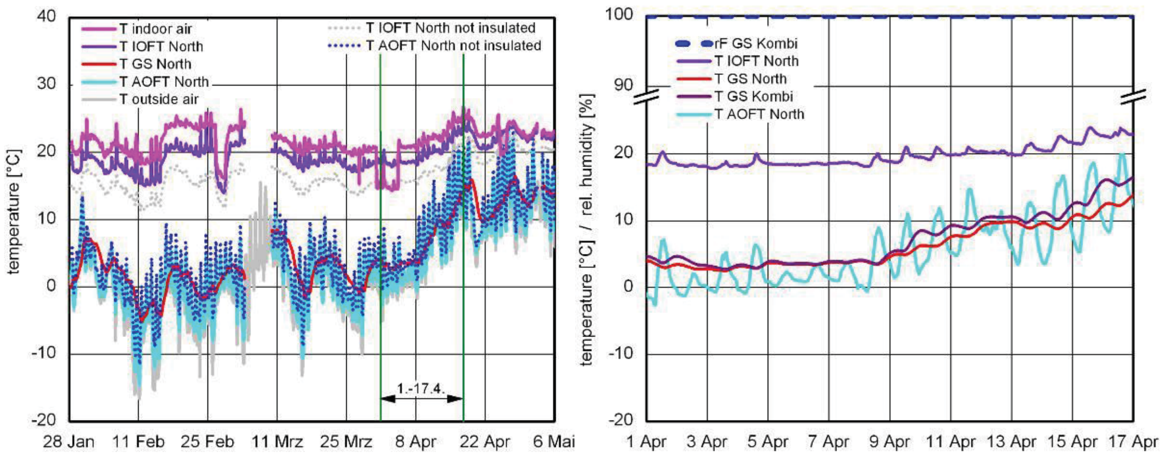

FIG 6. The left graph shows the temperature course of the north wall from 28th Jan to 6th May 2013. T AOFT names the outer surface temperature, T GS the temperature of the original surface behind the internal insulation, T IOFT the inuslated wall surface temperature inside. The right graph shows the period form 1st April to 17th April 2013 with relative Humidity and temperatur courses, whereas TGS Kombi and RH GS Kombi names the temperature and relative Humidity on the orgininal surface unterneath interal insulation.The level of RH is constant at 100 % RH.

3. Simulation

Further computational studies were carried out on the basis of the first simulation which were calculated with the measured data as boundary condition and compared to measured data in the interstitial layer. The influence of the assumed backside air flow was taken into account and the results of the simulation were also compared to the measured data. With this calibrated simulation long term calculations were performed with and without backside air flow and their impact calculated on the moisture balance. For the boundary conditions for the long term calculation a typical indoor moister load of residential housing between 40 % RH at 20 °C in winter and 60 % RH at 22 °C in summer were used. For the outdoor climate the Holzkirchen climate of 1991 were implemented and repeated for 10 years. The heat transmission coefficient was assumed outside with 0.0588 [m²*K/W] and indoors with 0.125 [m²*K/W]. The results on the water content of the plaster and brick wall are shown in (FIG 7) on the left side and the temperature and relative humidity course on the surface of the original plaster underneath the adhesive mat on the right side in (FIG 7). The leaky construction with backside air flow shows for the plaster with the red line a certain increase in the water content within the annual cycle and also a long term increase over ten years. The water content of the brick wall with backflow air current is only increasing slightly compared to the tight construction. The relative humidity shows a similar behavior to the plaster with an annual cycle and a continuous small long term increase.

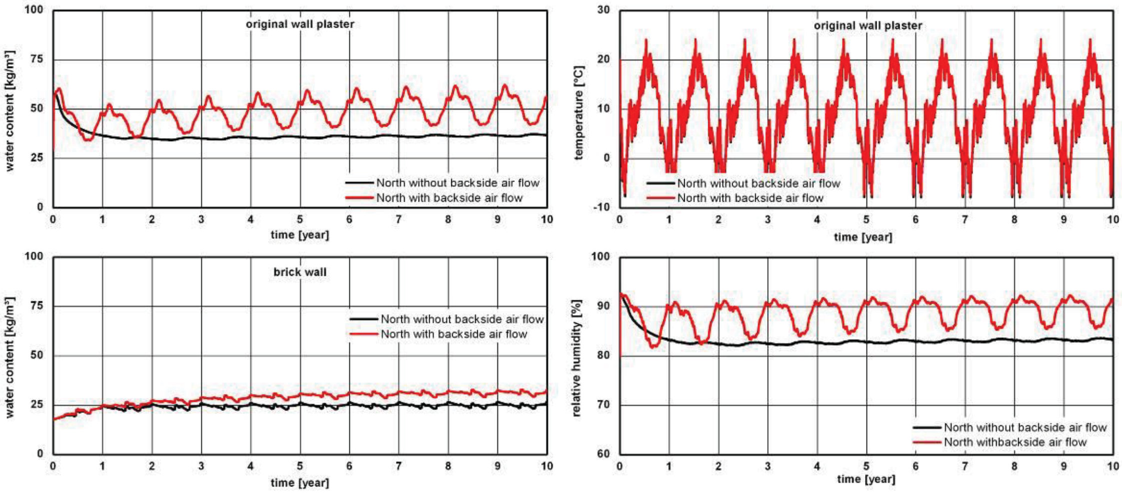

FIG 7: Sequence of water content in the existing original wall plaster and brick wall of the north side with and without backside air flow of the VIP interior insultion over a time span of ten years. The right graphs shows the temperature and humidity on the surface of the original plaster underneath the interstitial layer between original plaster and new applied adhesive mat calculated with tight (black line) and leaky (red line) construction on a north oriented facade over a time span of ten years.

To assess the influence of the increase of moister in the construction an additional simulation with WUFI® Bio (Sedlbauer 2001) was performed on the results of the previous simulation. With this tool a predicted mould growth can be calculated based on relative humidity, temperature and substrate with transient boundary conditions. With combining the results of the bio hygrothermal model with the mould index of the Viitanen model (Viitanen H. & Ritschkoff A.1991) it is possible to use an accepted and demonstrative measure for WUFI® Bio (Krus et al 2011). The mould index reaches from 0 (no mould growth) to 6 (100 % mould coverage of the surface).

With a mould index of 3 a mould growth is clearly visible. For Mould Index below 1 only low risk of mould growth exists. In (FIG 8) the Mould-Index is calculated for the shown data in (FIG 7) of the 10th year with and without backside air flow. The simulation with backside air flow shows a visible mould growth. If the construction is tight only a very low risk of mould growth can be calculated at that position of the wall construction.

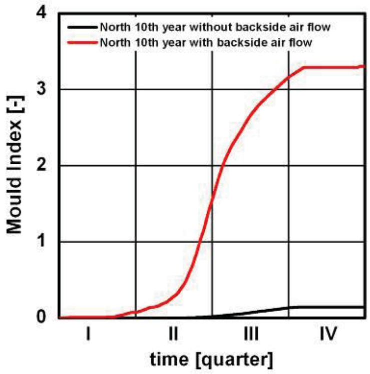

FIG 8. Sequence of the mould-indexes in the interstitial layer between original plaster and new applied adhesive mat calculated with tight and leaky construction on a north oriented facade of the last calculated year.

4. Conclusions

The investigations for removable assembly contribute to a significant development of reversible internal wall insulation. It was possible to dismantle the VIP largely non-destructive to the orginal surface. The results in terms of the conservation status of the colored surfaces and changes of the colors are encouraging. The mold growth by backside air flow could not be resolved despite the effort for sealing. With simulation the effect of the background current was reproduced and the long-term performance was calculated. From the perspective of conservation of historic surfaces the separation with lamination of the original surface from the cement adhesive is a promising option for internal insulation.

5. Acknowledgements

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