Calculative investigations on the "Temperierung" wall heating system – Hygric and thermal aspects

M. Krus & R. Kilian
Fraunhofer Insitute for Building Physics, Holzkirchen, Germany

ABSTRACT: The aspects of reducing rising damp and energy use of the Temperierung wall heating system are examined with hygrothermal 2D building simulation. In comparison to the non-heated walls the change of moisture profiles, the heat losses by heat transmission and the moisture flux from the outer wall to the room are shown.

1 INTRODUCTION

The "Temperierung" method is often used in historic buildings. It is based on providing continuous heating to the building envelope. Normally this is done with heating tubes installed in the plaster on the inside of outer walls or painted pipes on the surface of the walls. This creates in general a homogenous distribution of heat on the surfaces of the room except near the pipes and can help to reduce draughts.

The system will heat the most critical points in the construction (corners) where otherwise often condensation happens. Thereby it helps to prevent mould or algae growth in massive buildings.

Two much discussed aspects of the system are an assumed reduction of rising damp and a supposed general low energy demand due to the drying out of the walls. To give answers to these questions hygrothermal 2D building simulations are applied on a case study – the St. Renatus Chapel in Lustheim from 1686, built by Henrico Zuccalli. In comparison to the non-heated walls the change of moisture profiles, the heat losses by heat transmission and the moisture flux from the outer wall to the room are shown.

The Chapel is situated in the park of Schleißheim Castle near Munich and showed severe moisture damages in the second half of the 20th century. Therefore a horizontal moisture barrier was carried out in the early 1970ies that showed no effect at all. Most of the moisture in the Chapel came from condensation of moisture during summer. In the course of major restoration works a "Temperierung" wall heating system was introduced in 2003. The effect on the indoor environment was recorded and documented (Kilian 2004, Kilian 2007). By raising the temperature level of the church, the level of relative humidity was lowered from a mean of 70% rh to 50% rh. Also a slightly raised absolute humidity in comparison to outdoors was recorded after installing the "Temperierung" system that meant an additional source for moisture in the building. By making the windows more airtight also the short term fluctuations could be lowered. In 2010 the building is still in very good state, except for salt crystallisation on some parts of the exterior walls.

Since restoration the building is used only for weddings in the summer and is heated continually for conservation reasons during the colder seasons of the year.

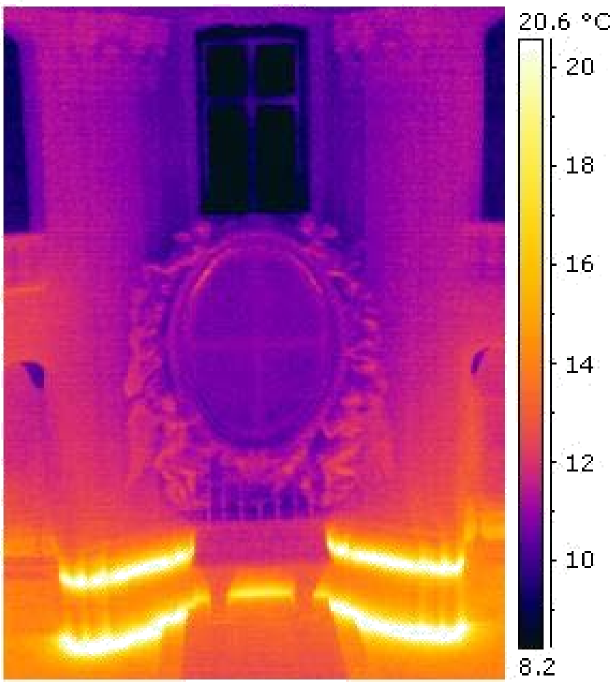

Fig. 1: The thermography of the Renatus Chapel shows clearly the wall heating of building components. Above the heated zone, the temperature distribution is homogenous.

2 BACKGROUND AND OBJECTIVE OF CALCULATIVE INVESTIGATIONS

In case of locally high moisture contents in materials on internal surfaces caused by rising damp, condensation in summer or other effects, the advantages concerning the wall heating (Temperierung) of building components are controversial. This technology allows the reduction of moisture in certain problematic areas and can avoid for example microbial growth. But it is consistently argued that the wall heating of building components is also an energy-saving way of heating a room. The reasons given for this fact are that due to the drying of a wall the thermal conductivity of the material decreases, and thus heat transmission losses are clearly reduced in comparison to a conventional heating, resulting in a considerable energy-saving effect. With regard to the application in the Renatus Chapel additional problems arise concerning the effect of such wall heating. With this example of rising damp in the foundation it is especially important to know whereto the released moisture is transported. Is the wall section drying mainly towards the outside or towards the inside? Is the capillary transport, which is caused by rising damp, significantly reduced by wall heating or even permanently intensified?

These questions cannot be answered by measurements, since it is impossible to determine in situ moisture mass flows in the wall construction caused by diffusion or capillary transport processes. Therefore, calculative investigations are carried out to solve these problems. They allow to analyse the processes in the brickwork as well as to compare conventional heating and wall heating of building components under the same boundary conditions.

2.1 *Calculative investigations*

A tested and validated one-dimensional and two-dimensional EDV program WUFI®-Pro and WUFI®-2D (Künzel 1994) is available at Fraunhofer IBP for the calculative investigation of coupled heat and moisture transfer processes. Previous statements on the moisture transfer behaviour of building materials by means of this method showed good compliance of calculations and experimental investigations at the object (Künzel & Krus1995; Künzel 1999).

To carry out calculations, a wall construction is implemented which is as similar as possible to that of the Renatus Chapel. Material parameters were derived from the WUFI® materials database and modified for better compliance, where necessary.

The Munich test reference year is applied as outdoor climate. The indoor climate is based on measurements and is similar to the course of a year with an indoor temperature between 8 °C and 20 °C and a relative humidity from 40 % to 65 %. The orientation of the wall is towards the north so that the impact of driving rain and solar radiation can be neglected to a large extent.

Fig. 2 shows the implemented construction. The wall consists of solid bricks and has a lime plaster on both sides. A horizontal barrier is installed approx. 10 cm above ground as in the real Renatus Chapel. The flow pipe for wall heating building components is directly behind the internal plaster with a thickness of 1.5 cm in the middle of ground and horizontal barrier. The return pipe is 1 m above ground, i.e. clearly above the horizontal barrier. The flow temperature amounts to 60 °C, return temperature is 55 C. The foundation is permanently in ground water so that rising damp occurs. In Fig. 2 the entire construction implemented for calculations is represented. The same construction is applied for calculations without wall heating of the building components but without heating pipes.

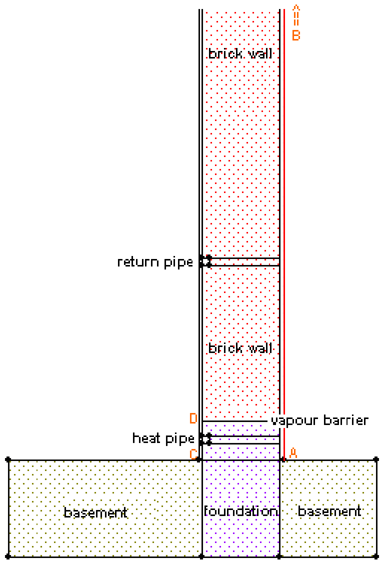

Fig. 2: Implemented construction to calculate hygrothermal processes in case of wall heating of building components as in the example of the Renatus Chapel.

2.2 *Results*

2.2.1 *Drying by the wall heating*

Fig. 3 shows the course of the water content in the foundation beneath the horizontal barrier. It can be clearly seen that even without wall heating of the building components drying takes place by simply heating the room. Because the calculations starts with saturated material in this section a drying can be observed also without wall heating. However the heating of the wet building components results in intensified drying.

The faster drying with heating of the building components is caused by the intensive local heating of the brickwork. This is obvious from the temperature distribution as represented in Fig. 4 for a selected time in winter. Fig. 5 (bottom) represents the distribution of water content for the situation without wall heating after 1.5 years. Certain drying towards the inside and outside is evident. Compared to the result of the situation with wall heating (Fig. 5 top), the strong drying around the heating pipe is apparent. Stronger drying can also be found in the outside section. The reason for this is that the temperature level of the whole wall is higher in comparison to the situation without wall heating.

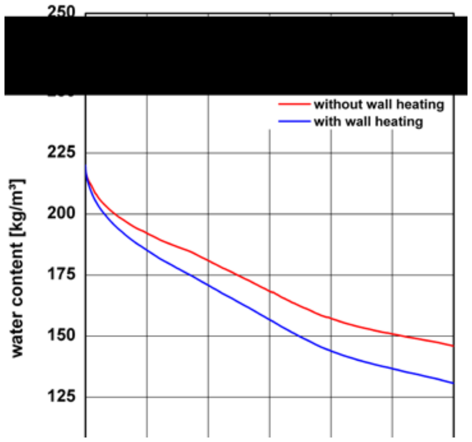

Fig. 3: Course of water content in the area beneath the horizontal barrier without (red line) and with (blue line) wall heating.

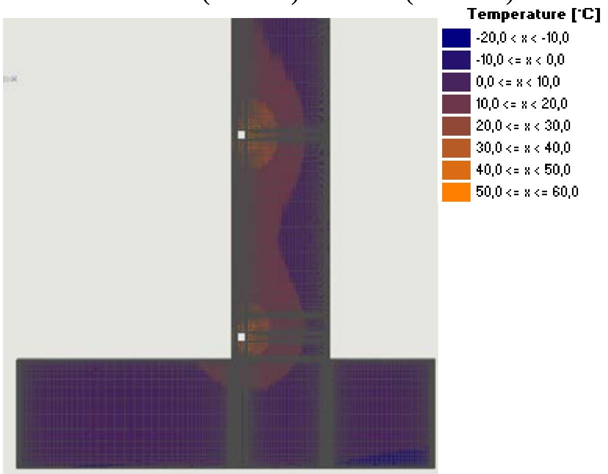

Fig. 4: Calculated temperature distribution in winter (Feb. 15th).

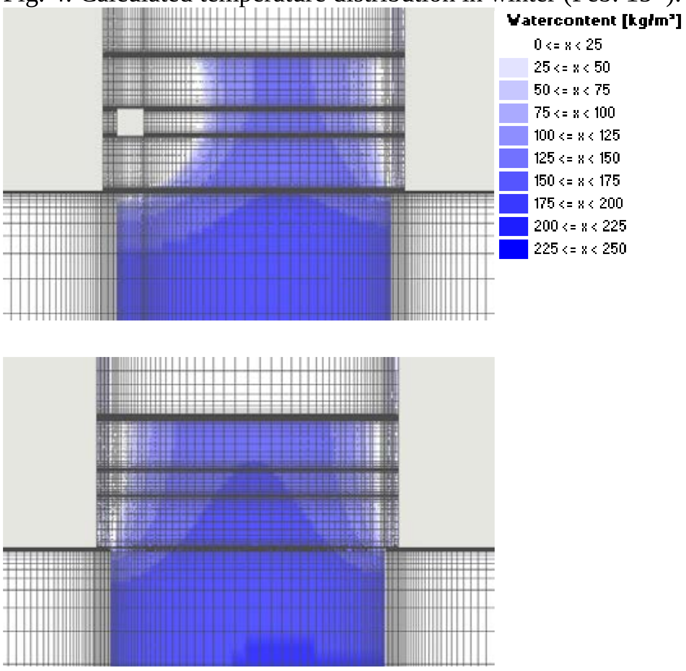

Fig. 5: Calculated moisture distribution after 1.5 years without (bottom) and with wall heating (top).

2.2.2 *Energy consumption*

To test whether wall heating represents an energy-saving way of heating due to the drying of the walls, the evolution of the energy flow on the external wall above floor level (between point A and B in Fig. 2) with and without wall heating is compared. Since investigations are based on the same indoor climate in both cases, potential energy savings should be identified. It is, however, obvious that remarkably higher heat flows occur with wall (see fig. 6). Moreover, wall heating of the building components is also operated beyond the usual heating periods.

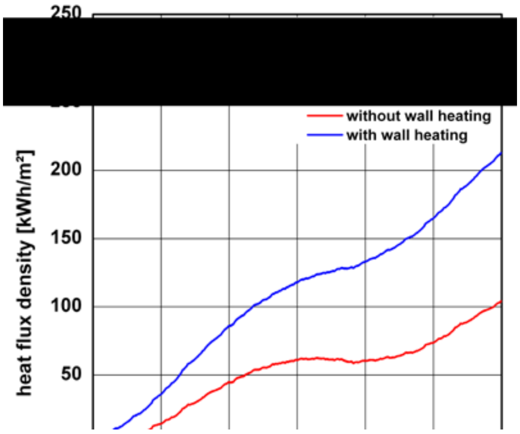

Fig. 6: Integral courses of the heat flux densities with (blue line) and without wall heating (red line).

Considering the thermal resistance or thermal transmittance of the wall explains this fact. At the end of the calculation the mean water content amounts to 113 kg/m³ without wall heating, and to only 75 kg/m³ with wall heating. Thus, the thermal resistance of the brick wall increases from 0.34 m²K/W to 0.42 m²K/W. Heat transfer, however, takes place directly in the wall in case of wall heating so that the thermal resistance from indoor air to the wall is negligible. Therefore the thermal transmittance increases from 1.9 to 2.2 W/m²K.

2.2.3 *Rising damp*

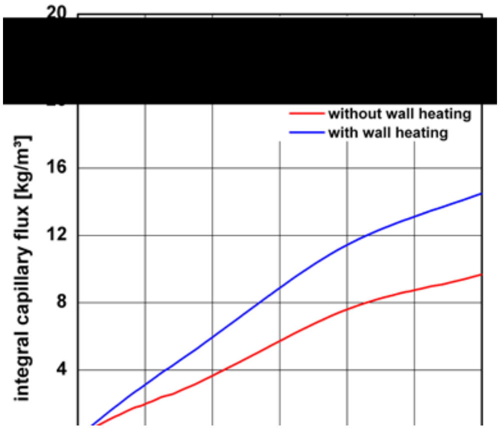

Fig. 7: Integral courses of capillary flow densities over C-A (see Fig. 1) for the construction with (blue line) and without wall heating (red line).

Fig. 7 represents the capillary flow over C-A (see Fig. 2). A higher capillary flow results from wall heating in comparison to the situation without wall heating. The reason is that due to the drying in the section around the heating pipe the water content gradient is higher and thus the driving force for capillary transport as well.

2.2.4 *Diffusion towards the inside*

Fig. 8 (top) shows the integral course of the diffusion flux over C-D (see Fig. 2), i.e. towards the interior. Wall heating results in a significantly higher diffusion flow than without. The fact is that a large part of the moisture is emitted to the interior. The representation of the diffusion flux density in Fig 8 (bottom) shows that the difference to the non heated case is extremely high in the beginning. The high water content at the beginning is given off very rapidly causing extremely high diffusion flows towards the interior. An almost steady state, however, is reached after approx. 10 months resulting in an almost parallel course from this time. With wall heating, however, the diffusion flow towards the interior is still significantly higher, approx. double as high.

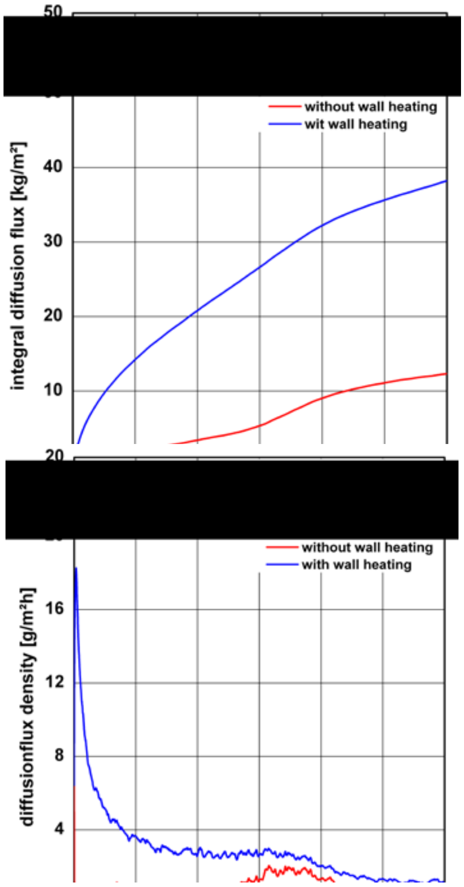

Fig. 8: Integral courses of diffusion flux (topt) and diffusion flux densities (bottom) over C-D (see Fig. 1) with (blue line) and without wall heating (red line).

3 SUMMARY

Two-dimensional transient calculations were carried out to assess the hygrothermal processes with the Renatus Chapel as an example. The purpose of the investigations was to answer the questions occurring with the wall heating systems.

Calculations confirm that the wall heating comes up to the real task, i.e. to dry vulnerable building components rapidly, and to avoid damage caused by microbial growth or frost. But it does not represent an energy-saving way of heating. Even if the drying of the brickwork results in a reduction of the thermal conductivity, the lack of the internal heat transmission resistance, which is of significant importance due to the typically inadequate insulation standard of the brickwork, will cause higher heat flows towards the outside all in all.

As calculations show it is necessary to take into consideration that due to the increased water gradient the wall heating may cause the intensification of rising damp. This does not mean that the water keeps on ascending, since clearly increased evaporation takes place due to the locally elevated temperature. The capillary flow, however, beneath the wall heating will be increased. As a worst-case scenario this means the enhanced accumulation of salt in the brickwork, and therefore this fact should be taken into consideration in each individual case of assessing the measures.

The computation also shows that the wall heating may cause an enhanced diffusion flow to the interior. This is most obvious in the beginning of wall heating, since a large amount of water is released from the brickwork at this time. But even under long-term operation an increased diffusion mass flow towards the interior can occur. This can result in an increase of indoor humidity. In general an enhanced removal of moisture must be cared for at least during the first months after the start of operation.

If correctly applied, the wall heating is a reasonable and appropriate measure in many cases to preserve precious cultural heritage. Against this background, other topics, e.g. energy saving, may be of secondary importance in these cases.

4 REFERENCES

Kilian, R. 2004 *Die Wandtemperierung in der Renatuskapelle in Lustheim – Auswirkungen auf das Raumklima*, Siegl Verlag, München

Kilian, R. 2007 *Statistische Untersuchungen der Klimaschwankungsbreite in unterschiedlich genutzten Kirchenbauten*, in: *WTA Almanach 2007*, WTA-Publications, München .

Künzel, H.M. 1994. *Verfahren zur ein- und zweidimensionalen Berechnung des gekoppelten Wärme- und Feuchtetransports in Bauteilen mit einfachen Kennwerten*. Dissertation Universität Stuttgart.

Künzel, H.M. 1999. *Praktische Beurteilung des Feuchteverhaltens von Bauteilen durch moderne Rechenverfahren*. WTA-Schriftenreihe, Heft 18, Aedificatio Verlag.

Künzel, H.M. & Krus, M. 1995. *Beurteilung des Feuchteverhaltens von Natursteinfassaden durch Kombination von rechnerischen und* experimentellen Untersuchungsmethoden. Internationale Zeitschrift für Bauinstandsetzen 1, H. 1, S. 5-19.