LOCAL HEATING OF THERMAL WEAK POINTS

Dr.-Ing. Martin Krus
Fraunhofer Institute for Building Physics, Fraunhoferstraße 10, 83626 Valley, Germany,
martin.krus@ibp.fraunhofer.de

M. BP Sabrina Wurm
Müller-BBM GmbH, Am Bugapark 1, 45899 Gelsenkirchen, Germany Sabrina.Wurm@MuellerBBM.d

Summary

Within the framework of this paper it is investigated, whether it is more reasonable to use local heating to avoid mould growth on thermal bridges than a higher ventilation rate of the rooms in question with the respective higher heat losses due to ventilation. Three different thermal bridges, external wall edge, balcony slab and floor slab support, are investigated at the locations Hof (cold location), Würzburg (moderate location) and Freiburg (warm location). A common apartment located in the center of a multi-story apartment house is taken as a basis for investigations. On the basis of a „basic“ air change rate of 0.3 h^{-1}, when mould growth occurs on all three thermal bridges, it is investigated from which ventilation rate mould growth can be avoided at the respective location and on the selected thermal bridges, and how much heat loss for ventilation is generated. Then, with the same „basic“ air change rate the use of a heating cable is simulated as an alternative to the additional ventilation rate, whereby the heating capacity of the heating cable as well as the operation period can be varied. The energy demand and the primary energy demand are compared.

It is obvious that the energy demand for the use of the heating cable is lower at all investigated thermal bridges and locations than for the additional window ventilation. However, if the primary energy demand is compared by considering the primary energy factor of the various energy carriers, the use of the heating cable is not always the better choice. This is especially true, if energy carriers with a smaller primary energy factor are used for heating (district heating or regenerative energies).

The air change rate of 0.3 h^{-1} taken as a basis may be realistic in numerous cases, but represents only the lower limit of usual ventilation rates in the stock of existing buildings. Anyhow, for an air change rate of 0.5 h^{-1}, which is characteristic for old buildings and frequently achieved by the infiltration air change alone, the use of the heating cable to avoid mould growth is more energy-efficient than a higher rate of window ventilation. Moreover, as experience shows, users only rarely change their ventilation behaviour so that the requirements of higher rates of window ventilation usually show little effect. In many cases, a higher air change rate could only be achieved by air-conditioning systems.

From the building physical and energetic point of view it is reasonable to solve the problem of thermal bridges by adequate measures of thermal insulation. Since these thermal insulation measures are not easily accepted by owners and according to local conditions their realization is complex and expensive, the additional heating of thermal weak points at least as a temporal solution is an adequate measure from the energetic as well as financial point of view, which can be better suited than additional window ventilation. However, the additional risk of fire must also be taken into consideration. This kind of electrical heating should not be used in any case to avoid mould growth behind furniture placed in front of external walls with insufficient thermal insulation. It would be a better solution to relocate the furniture in this case.

Keywords: Thermal bridges; local heating

1 Introduction

Considerable efforts are necessary to renovate thermal weak points for example in the corners of already existing buildings. Even if thermal insulation of weak points is sustainable in the long run, enhancing ventilation is frequently supposed to avoid mould growth or staining due to moisture. In addition to the heat loss via thermal bridges heat losses caused by ventilation occur. This paper deals with the problem, whether in case of typical thermal weak points it can be more reasonable to use local electrical heating instead of a higher rate of ventilation, which is difficult to assess by the users (see also previous investigations [1]).

2 Procedure of investigations

To clarify this question computer programs of the WUFI® family are applied, the mould prognosis program WUFI®-Bio, the two-dimensional calculation program WUFI®-2D as well as the room model WUFI®-Plus [2-4], allowing the hygrothermal and energetic simulation of the previously described situation [5-9]. The energy demand as well as the primary energy demand is compared, since from the ecological point of view the result is dependent on the energy source used for heating. The investigations are based on the research of the typical problems of thermal bridges occurring in already existing buildings as well as of commercial heating cables and heater foils [10].

The influence of enhanced ventilation and the use of a local electrical heating by heating cable to avoid mould at thermal bridges are compared with the energy input required for this purpose. Calculations are conducted for a model apartment in a typical building of the stock of existing buildings. Three climate locations - Hof, Würzburg and Freiburg – are selected as representatives of a cold, moderate and warm location in Germany. On the basis of an exemplary occupation by 2 adults and 2 children the climatic indoor conditions are determined for these model apartments over a period of a year by means of WUFI®-Plus. Then, the selected thermal bridges are modelled by means of WUFI®-2D, and the moisture and temperature values on the surface of the thermal bridge are determined by means of the respective climatic indoor conditions in relation to the location. Based on this data set by means of WUFI®-Bio it is calculated, whether mould growth is to be expected. Thereby class I is selected as substrate class comprising biologically recyclable substrates, e.g. wall papers, plasterboard, and building products made of biodegradable raw materials and materials such as permanently elastic joints [2].

In the process, the air change rate is varied for each location to determine from which air change rate mould growth does no longer occur on the respective thermal bridge. Test calculations showed that mould growth at the chosen thermal bridges occurs at an air change rate of 0.3 h^{-1} but it does not occur on undisturbed wall surfaces [10]. Based on this minimum air change rate and a minimum indoor temperature of 20°C the requirement of energy for enhanced ventilation to avoid mould growth in the range of thermal bridges is calculated. Thereby, the air change rate is increased in steps of 0.1 h^{-1} until mould growth must no longer be expected on the thermal bridges. Then, a heating cable with varying performance is modelled at the thermal bridge at an air change rate of 0.3 h^{-1} in WUFI®-2D to determine the influence on the calculated mould growth during the phase of usage in this case. For the purpose of a simple solution the heating cable is permanently operated without any performance regulation during the phase of usage.

2.1 Apartment in the stock of existing buildings

The apartment is supposed to be located in the centre of a multi-storey apartment house so that due to the same use there is no thermal or hygrothermal transmission upwards or downwards (Fig. 1). External dimensions amount to 9 m x 12 m at a room height of 2.8 m. The building has external walls of a total thickness of approx. 40 cm made of brick work with external cement plaster and internal gypsum plaster. The thermal transmittance of this wall is approx. 1.1 W/m²K. Floor and ceiling are made of concrete with a layer of floating screed. The hygrothermal material properties are taken from the WUFI® material database. The apartment is equipped with windows with double glazing typical for old buildings and a U-value of 2.7 W/m²K. The performance of the heating system amounts to 25 kW.

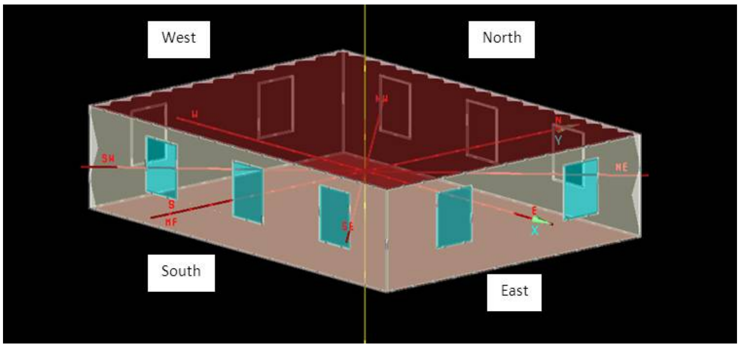

Fig. 1 *View of the model apartment with indication of orientations.*

2.2 Moisture and thermal loads

Moisture loads mainly results from the persons present, their respiration and transpiration as well as user behaviour, see Table 1. In the context, taking showers or a bath, cooking, doing the dishes, drying laundry and evaporation from plants are considered. The calculations are based on the assumption that the old-building apartment is occupied by two adults and two children and with 6 potted plants (equivalent to 10 g/h). Laundry is dried in the apartment (equivalent to 100 g/h), in addition, drying the towels in the bathroom and kitchen is also considered (equivalent to 40 g/h). The moisture transfer is deliberately assumed to be higher than average. Energy losses by heat conduction are not considered in the calculations, since in absolute terms they entail a change of the required heating energy, but has no influence on the comparison of ventilation and the application of the heating cable.

Tab. 1 *Daily humidity input in model apartment.*

Time of day	Activity	Amount of humidity [g]
22:00 to 06:00	4 persons sleeping	2.320
06:00 to 07:00	taking showers, 4 persons present	1.150
07:00 to 08:00	cooking coffee/tea, 4 persons present	475
08:00 to 09:00	4 persons present	350
09:00 to 16:00	apartment unoccupied	1.050
16:00 to 18:00	2 persons present (children)	500
18:00 to 19:00	cooking, 4 persons present	825
19:00 to 20:00	taking showers 2 persons, doing the dishes, 4 persons present	1.035
20:00 to 21:00	2 persons sleeping (children), 2 persons present	320
21:00 to 22:00	taking showers 2 persons, 2 persons (children) sleeping, 2 persons present	730
Total amount		8.755

2.3 Setup of investigated thermal bridges

As typical thermal bridges an external wall edge in north-east orientation, a shaded continuous concrete balcony slab with a thickness of 16 cm, as well as a floor slab support are investigated. Considering the particularly problematic heat transfer directly at the edge the heat transmission resistance on the internal surface area towards the edge was successively increased according to Figure 1. The external heat transmission resistance R_{se} is set to 0.04 (m²K)/W.

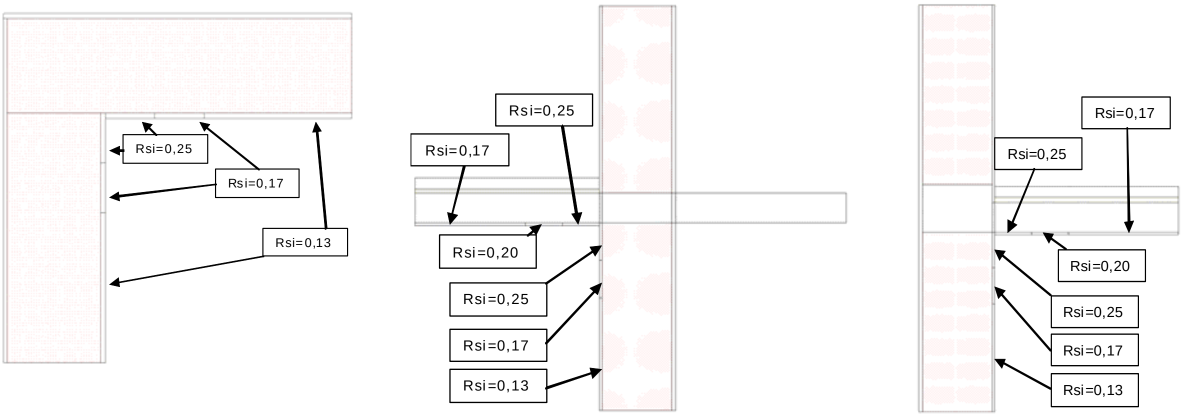

Fig. 2 *Setup of external wall edge (left), balcony slab (centre) and floor slab support (right). Local heat transmission resistances in m²K/W are integrated in the drawing.*

2.4 Operation by means of heating cable

The period from the beginning of September until the end of March was assumed as period of operation of the selected heating cable for calculations. This is the average heating period at the three locations. A more detailed investigation of the heating periods in relation to the location was negligible, since it can be assumed that tenants tend to realize operation intervals related to whole months. Depending on the results for the respective locations shorter operation periods will be iteratively calculated. In the period from the beginning of April until the end of August, however, there is principally no operation, since it is assumed that during these months mould growth on the selected thermal bridges is avoided by repeated ventilation and thus a higher rate of air exchange.

The selected heating cable has a heating power of 15 W/m. According to the result, heating cables with lower or higher heating power are used for simulations. Since the three investigated thermal bridges are linear thermal bridges a heater foil is not adequate in this case. The heating cable is installed directly at the place of lowest temperature of the thermal bridge (determined by means of WUFI®-2D) and continuously operated during the heating period.

3 Results and assessment

3.1 Avoiding mould growth by ventilation

Tab. 2 *ventilation heat losses to avoid mould growth*

air change [h^{-1}]	**external wall edge**	**balcony slab**	**floor slab**	**heat losses by ventilation [kWh]**
		Hof		
0.3	mould	mould	mould	2.637
0.4	mould	mould	mould	3.518
0.5	mould	mould	no mould	4.399
0.6	mould	no mould		5.280
0.7	no mould			6.162
		Würzburg		
0.3	mould	mould	mould	2.216
0.4	mould	mould	mould	2.954
0.5	mould	mould	mould	3.692
0.6	mould	no mould	no mould	4.430
0.7	no mould			5.168
		Freiburg		
0.3	mould	mould	mould	1.969
0.4	mould	mould	mould	2.623
0.5	mould	mould	no mould	3.278
0.6	no mould	no mould		3.931

The results for natural ventilation of the three locations are summarized in Table 2. It is obvious that mould growth on the external wall edge is avoided only from a mean air change rate of 0.7 h^{-1} in Hof as well as in Würzburg. The reason for this fact is of course the relatively high moisture load assumed. In Freiburg, the risk of mould growth no longer exists from a mean air change rate of 0.6 h^{-1} due to the warmer climate. The heat losses by ventilation are also listed in the Table to determine the additional energy demand caused by additional ventilation to avoid mould growth on thermal bridges.

3.2 Use of heating cable to avoid mould growth

Calculations carried out in [10] showed that the heating cable with a heating capacity of 15 W/m is best suited to avoid mould growth on the external wall edge. It cannot be secured that a heating capacity of 10 W/m is sufficient to avoid mould growth, and a heating capacity of 20 W/m generates an unnecessary surplus. A heating cable with a capacity of 10 W/m is sufficient for the thermal bridges of the balcony slab and the floor slab. It is most reasonable in all cases to use the heating cable over the total period from the beginning of September until the end of March.

The total thermal output of the heating cable needed to avoid mould growth on various thermal bridges is listed in Table 3. It is assumed that besides the balcony slab also the two external edges with north-east and north-west orientation as well as the floor slab support with northern orientation must be heated. Due to the same operation period the same energy demand occurs for all three locations.

Tab. 3 *Determination of the heating capacity required for the use of a heating cable to avoid mould growth.*

thermal bridge	heating capacity [W/m]	length [m]	number [piece]	operation period [h/a]	total thermal output [kWh/a]
external wall edge	15	2,8	2	5.124	430
balcony slab	10	5,0	1	5.124	256
floor slab support	10	12,0	1	5.124	615

3.3 Comparison higher ventilation– use of heating cable

The additional energy input to avoid mould growth is listed in Table 4, whereby the difference to a ventilation rate of 0.3 h^{-1} was taken as a basis for ventilation.

Tab. 4 *Comparison of the energy demand for ventilation additional to an air change rate of 0.3 $h^1$and the use of a heating cable.*

Thermal bridge	additional demand of ventilation to air change rate 0.3 h^{-1}						heating cable
	location Hof [kWh]	air change rate [h^{-1}]	location Würzburg [kWh]	air change rate [h^{-1}]	location Freiburg [kWh]	air change rate [h^{-1}]	All three locations [kWh]
external wall edge	3.525	0.7	2.952	0.7	1.962	0.6	430
balcony slab	2.643	0.6	2.214	0.6	1.962	0.6	256
floor slab support	1.762	0.5	2.214	0.6	1.309	0.5	615

It is evident that at all three locations and for the three thermal bridges investigated the use of a heating cable reduces the energy demand considerably in comparison to a higher ventilation rate to avoid damages by mould growth. The air change rate of 0.3 h^{-1} taken as a basis may be realistic in numerous cases, but represents rather the lower limit of usual ventilation in the stock of existing buildings. For this reason, the result of a more characteristic air change rate of 0.5 h^{-1} is represented in Table 5. In this context, the fact was disregarded that it would have been possible to use a heating cable with a lower heating capacity as well as to select a shorter operation period. Even as concerns the basic air change rate of 0.5 h^{-1} the energy demand for additional ventilation to avoid mould growth is still higher than for the use of the heating cable.

Tab. 5 *Comparison of the energy demand for ventilation additional to an air change rate of 0.5 h^{-1}and the use of a heating cable.*

Thermal bridge	**additional demand of ventilation to air change rate 0.3 h^{-1}**						**heating cable**
	location Hof [kWh]	**air change rate [h^{-1}]**	**location Würzburg [kWh]**	**air change rate [h^{-1}]**	**location Freiburg [kWh]**	**air change rate [h^{-1}]**	**All three locations [kWh]**
external wall edge	1.763	0.7	1.476	0.7	653	0.6	430
balcony slab	882	0.6	738	0.6	653	0.6	256
floor slab support	0	0.5	738	0.6	0	0.5	615*

* Only in Würzburg, since at the two other locations mould growth is already avoided by a air change rate of 0.5 h^{-1}.

In contrast to space heating the heating cable is operating by electrical energy. To assess the ecological impact the primary energy demand is listed in Table 6. A primary energy factor of 2.6 is taken as a basis for the electrical energy used for the heating cable. Since the apartments in the stock of existing buildings are usually heated by oil or gas, a primary energy factor of 1.1 is taken as a basis for the additional demand for ventilation.

Tab. 6 *Comparison of primary energy demand for ventilation additional to an air change rate of 0.3 h^{-1}and the use of a heating cable.*

Thermal bridge	**additional demand of ventilation to air change rate 0.3 h^{-1}**						**heating cable**
	location Hof [kWh]	**air change rate [h^{-1}]**	**location Würzburg [kWh]**	**air change rate [h^{-1}]**	**location Freiburg [kWh]**	**air change rate [h^{-1}]**	**All three locations [kWh]**
external wall edge	3.878	0.7	3.247	0.7	2.158	0.6	1.120
balcony slab	2.907	0.6	2.435	0.6	2.158	0.6	666
floor slab support	1.938	0.5	2.435	0.6	1.440	0.5	1.599

With regard to the primary energy demand a more favourable result is achieved by using the heating cable with the exception of the floor slab support in Freiburg, where a slightly higher primary energy demand occurs. These results, however, are modified, if energy carriers with a smaller primary energy factor are used for heating (district heating or regenerative energies).

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