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# Improving Durability of Wooden Beam Bearings in Inside Insulated Walls by Tempering the Beam's Heads

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## ABSTRACT

Improving durability of wooden beam bearings after a thermal renovation via interior insulation is highly demanding for planners. Because of an isolated thermal bridge in the area of the wooden beam head the risk of condensation water forming in this area increases after installing interior insulation. The problem with wooden beam ends has been analysed increasingly in the last few years by many research institutions as wooden ceiling constructions are common in existing buildings. Furthermore, thermal renovation makes a vital contribution regarding improving the energy-efficiency of existing buildings.

In this paper a method to temper wooden beam ends is introduced. It is a patent pending which is currently developed further using laboratory-prototypes in a double climate chamber. This technology is based on thermo conductive types of sheet metal, which are driven into the construction at the joint between the wooden beam and the surrounding masonry. The thermal energy is provided by a heating pipe and fed into the metal. Because of the metal's high thermal conductivity, heat can be fed specifically into the beam's end in order to avoid wood rotting at this crucial point.

Calculating the beam's end temperature control was done using three-dimensional HAM simulations with air flows in the ceiling cavity being taken into account. The results of different measurements in the double climate chamber as well as the HAM simulations clearly show that the durability of an interior insulation can be increased via a temporary and local tempering of wooden beam bearings. At the same time the risk of wood rotting at the ceiling's bearing structure is minimised.

Comparative analyses show that this method of tempering the beam ends is especially energy-saving as the energy input is low due to the special feeding of heat via thermo conductive types of sheet metal.

KEYWORDS

Wooden beam ceiling, interior insulation, 3D HAM model, local temperature control, double climate chamber

## INTRODUCTION

In-situ-measurements on existing buildings with wooden beam ceilings show that the thermal retrofitting via interior insulation can result in damage by moisture (IBO, 2017). Hygrothermal simulations (Wegerer and Bednar, 2017) prove this to be true and show that accompanying measures are to be made when planning an interior insulation with wooden beam ceilings. The interior insulation leads to the cooling-off of the entire outside wall in winter. The ceiling beams protrude into the cold area and are open to a greater risk of rotting. This can be prevented by a local, temporary heat input. The Research Center for Building Physics and Sound Protection at TU Vienna has developed a technology how the beam head area can be tempered. Thereby, harmful condensate formation can be prevented and thus the construction's durability secured.

At the same time, high energy efficiency and practical feasibilty were taken into account. A prototype for a local beam head temperature control was developed and a patent filed (Wegerer and Bednar, 2012).

**METHODS**

Extensive tests were made in a double climate chamber on a true-to-life, 45cm-thick brick wall which is equipped with a ceiling connection over the entire length of its warm side (see fig. 1). Temperature and humidity sensors to examine the hygrothermal conditions were mounted on the – altogether five – wooden beam heads (see fig. 2a). In the bearing areas, sensors to measure the surface temperature were adhered directly to the surrounding bricks (see fig. 2b). Additionally, sensors were built into the wall's cross section to also examine the masonry's hygrothermal behaviour. These sensors serve as a reference for the one-dimensional temperature and moisture field. Finally, temperature and thermal flow measuring foils were applied to the wall's surface to gather a reference of the thermal resistance in comparison to in-situ-measurements.

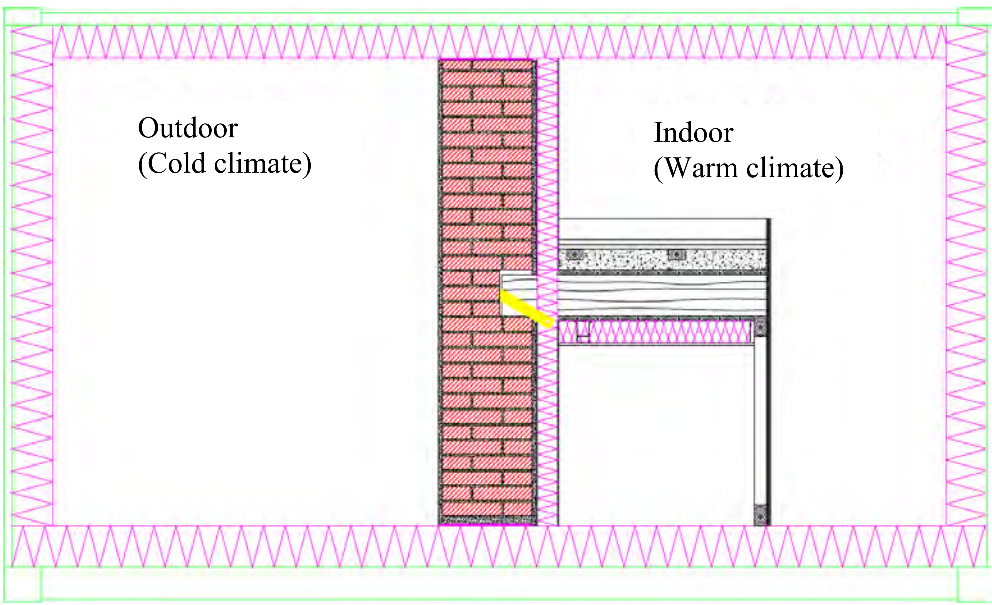



Figure 1. Cross section of the double climate chamber with test wall in middle. Ceiling structure is built into the right/warm climate side.

The tests in the double climate chamber were carried out in three phases. In the first testing phase, measurements were carried out on the test wall without interior insulation and without suspended ceiling. This construction corresponded with a typical existing wall of a Wilhelminian style house as it is found during renovation projects. The results were compared to in-situ-measurements to obtain true-to-life results during later tests with the test wall.

In the second testing phase, the wall was fitted with a 5cm-thick interior insulation made of Xella Multipor sheets. Furthermore, a suspended ceiling was constructed, as is currently usually the case with conventional renovations to improve noise protection. The results of the second testing phase provide information about the thermal enhancement of the existing wall and show the risk of moisture damage owing to the interior insulation. For a detailed analysis of the hygrothermal conditions, various climate scenarios were examined. In doing so, the outside climate was varied and the indoor climate was set with different moisture loads.

In the third testing phase, the beam head's temperature control was installed. Metal sheets made out of copper were driven into the airspace between wood and masonry with every wooden beam. A temperature sensor was stuck onto the outer end of every sheet (see fig. 3a). On the inner side, the heat conducting sheets were connected to a heating pipe (see fig. 4), which was laid in the interior insulation's area.


a) b) c)

Figure 2. Sensor arrangement a) on beam head ends, b) in the bearing area, c) beam heads before mounting in brick wall

a) b)

Figure 3. a) Prototype of heat conducting sheet, b) overhead beams without floor assembly

a) b)

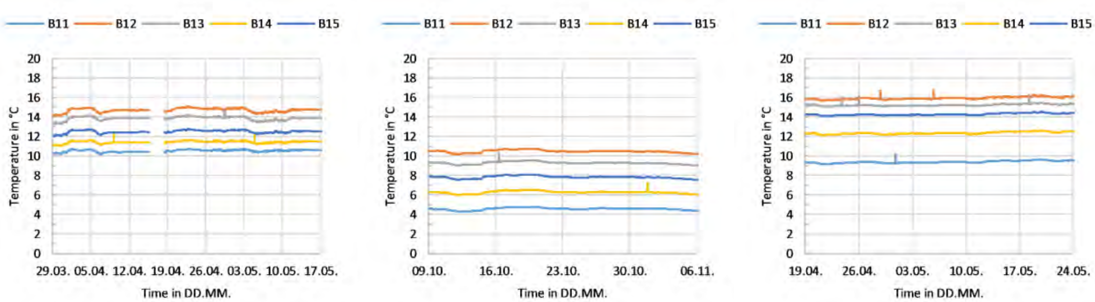
Figure 4. Installation of heat conducting sheets: a) view from below, b) view from side.

In addition to the measurements in the double climate chamber, hygrothermal simulations were made using Comsol Multiphysics and HAM4D_VIE. A model with dimensions geometrically identical to the test piece was generated in order to be able to validate the results and variations of every parameter. Besides, the energy demand was simulated and compared to real measurement data from the tests.

## RESULTS

### Temperature conditions at the beam's end

The results of the three testing phases show how the three-dimensional temperature field shapes itself within the different construction variants. The interior insulation's and temperature control's influences can be identified in the evaluations of the temperature field on the beam head's end. In figure 5, the measurement data of beam head 1 during the three testing phases are depicted exemplarily. It is evident that the installation of an interior insulation combined with a suspended ceiling leads to critical temperature conditions in the beam head area. This can be countered by temperature control of the beam head.




a) b) c)

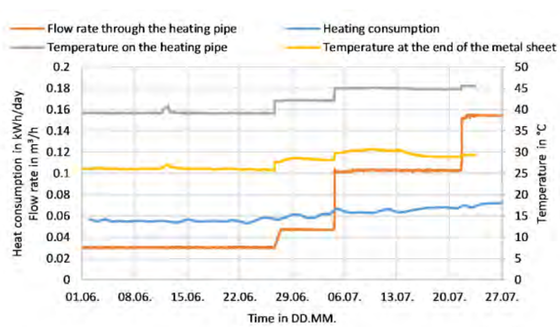
Figure 5. Temperature dispersion on beam head's end at stationary boundary conditions (-10°C outside temperature, 22°C inside temperature). Sensor positions as marked in fig. 2a: a) original construction, b) construction with interior insulation and suspended ceiling, c) construction with interior insulation, suspended ceiling and temperature control

The complex of problems regarding low surface temperatures near the beam head was elaborated by Wegerer and Bednar (2017). As a consequence of the perfusion near the airspace surrounding the wooden beam, warm and humid ambient air may condensate behind the wooden beam head resp. lead to mould growth or wood rotting.

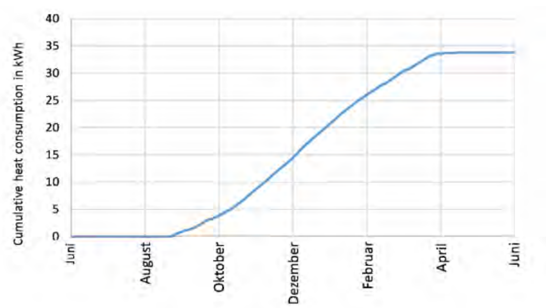
**Heating demand**

During the experiments with the tempering of the beam head in the double climate chamber the energy consumption was also measured. The application of energy via all five beam heads‘ heat conducting sheets could be calculated by taking into account the difference in temperature between the heating line’s flow and return as well as the flow rate. Additionally, the surface temperature was measured at every heat-conducting sheet directly at the junction from the heating pipe and at the outer end. The heat consumption and the flow rate as well as the surface temperatures are depicted in fig. 6a. Different scenarios were measured in which the same stationary climatic boundary conditions (-10°C outside and 22°C inside temperature) were always assured. The flow temperature was being held at a constant 45°C and only the flow rate was being varied. In spite of the sudden changes in temperature due to the flow rate’s increase, the heat input into the construction remains almost the same.

To calculate the reference heating demand a simplified simulation model, which provides temperature control of the entire ceiling connection area was generated. It was assumed that a minimum temperature of 15°C at the beam head’s end must not be gone below to prevent rotting of wood. The simulation model’s geometry is shown in figure 7 and corresponds to the test wall in the double climate chamber. Figure 6b shows the cumulative heat consumption over a year.



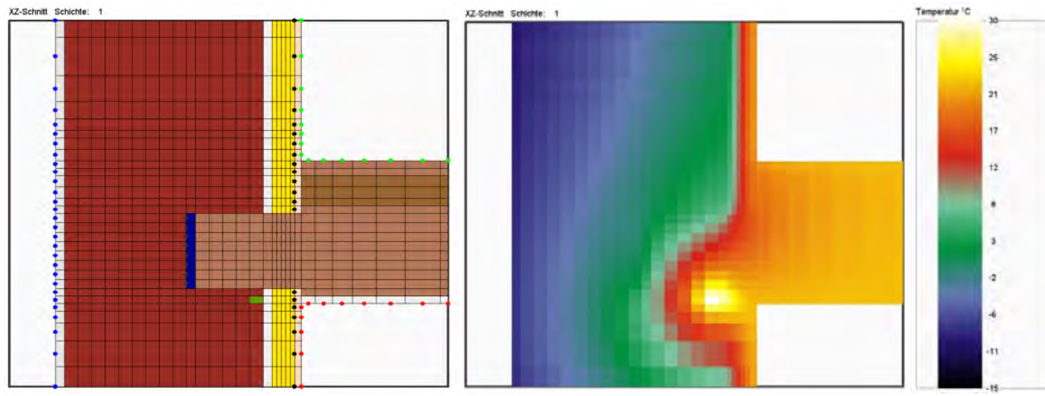

a)




b)

Figure 6. Heat consumption at respectively the same boundary conditions and component dimensions: a) energy consumption measured at prototype in the double climate chamber, b) Reference heating demand: simulated energy consumption corresponding to model in fig. 7 with temperature control of the entire ceiling connection area

From the data measured of the heat input per beam head (0.07kWh/day) and assuming a cold spell of two weeks (14 days), a yearly energy consumption of 1kWh per beam head can be gauged. If this is extrapolated onto a typical Wilhelminian style house, the theoretic energy demand of the beam head’s temperature control via heat conducting sheets averages at 200kWh per year, not considering distribution losses. The comparison of the two temperature control models shows that the local heat input via the heat conducting sheets is distinctly more efficient.




a) b) c)

Figure 7. Simulation model of a wooden beam abutment in HAM4D_VIE: a) geometry of model with green cell as source of heat (heating pipe), b) temperature field with flow temperature of 30°C, c) legend with temperature scale.

## DISCUSSIONS

The development of the prototype of a beam head's temperature control using a true-to-life brick wall has provided a wealth of data, which are of great relevance for construction practice. Currently, an interior insulation is installed in very little cases of existing constructions' renovations, however, the risk of damage of such construction is relatively high. With the selective temperature control of the beam abutments, greater insulation thicknesses and thus highly efficient renovations with interior insulation can be realised. The planning of such projects was in part dealt with in IEA Annex 55 (Bednar and Hagentoft, 2015), where a probabilistic calculation was developed.

## CONCLUSIONS

In practice, the planning of a beam head's temperature control is of little relevance at the moment. The technology introduced is, however, of great significance when thermally renovating buildings using interior insulation. For its practical implementation, the cost-benefit ratio has to be examined above all. The hydraulic dimensioning and the controlling means of the beam head's temperature control require further research. The calculation by hygrothermal simulation associated with this is currently being processed. Further measurements in the double climate chamber are to provide data for the CFD simulation model's validation.

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