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Evaluating the hygrothermal performance of wooden beam heads in 19th century town houses using in-situ measurements

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ABSTRACT

Improving the energy efficiency of typical 19th century townhouses in middle Europe the focus on the wooden beam bearing's hygrothermal performance has become more and more important during the last years. There are several issues for the risk of rotting of the wooden parts of the ceiling, because the retrofitting process of the masonry totally changes the hygrothermal conditions inside the wall. Applying an interior insulation or changing the air-tightness of the building envelope as well as the introduced moisture from the retrofitting process lead to a moisture increase inside the masonry and might cause rotting of the ceilings' wooden beam ends.

This paper introduces two demonstration objects which were retrofitted during the last years. Temperature and humidity sensors have been integrated at the wooden beams' ends to show the hygrothermal conditions during and after the retrofitting process. In the first building measurements started at the beginning of the renovation in September 2013 and are still being carried out. To compare different situations the monitored beam bearings are situated in two different retrofitted wall constructions, an inside insulated and a not insulated wall. Additionally, different indoor climates in the flats above and below the measured ceiling are monitored. In the second building 16 wooden beam heads situated in two different storeys with differing masonry thicknesses were measured. In this demonstration object the influence of building construction moisture from the renovation process as well as the drying out process were evaluated.

In conclusion, the wooden beam heads' durability will be assessed based on the measurement results and possible risk of damage influenced by the retrofitting process.

KEYWORDS

Wooden beam ceiling, interior insulation, in-situ measurements, hygrothermal performance

INTRODUCTION

During the course of the project „Improving Durability of Wooden Beam Bearings in Inside Insulated Walls by Tempering the Beam's Heads“ in-situ-trials on existing constructions with wooden beam ceilings were carried out in two late 19th century townhouses in Vienna. For a targeted analysis of the hygrothermal performance of wooden beam heads, sensors to measure temperature and relative humidity were installed in the floor-bearing-areas during a typical retrofitting process. Thus, the conditions in temperature and moisture could be examined during the state of construction and over the ensuing years of use.

Currently, no interior insulation is installed when a late 19th century townhouse is renovated conventionally, as there is no requirement for the thermal transmittance (U-value) with renovations according to the Austrian building code. However, due to noise abatement, a suspended ceiling is always mounted, which – because of the placement of mineral wool

results in cooling of the floor bearing area during wintertime. Future, energy-efficient renovations will stipulate the installation of an interior insulation, necessitating a detailed planning of accompanying measures on the ceiling-to-wall bearing. On the one hand, the measurement results document a long-term study on the functional efficiency of current methods of renovation. On the other hand, they form the basis for further research and the set-up of a bench test in a double climate chamber. The aim is to show that with constructions using interior insulation the floor bearing area cools of severely during winter and, because of the high relative humidity, the risk of wood rotting increases.

METHODS

Temperature and relative humidity sensors were installed in the construction of two demonstration buildings in selected apartments during the renovation works. Depending on the wooden beam's installation situation, the sensors were mounted in different positions. Figure 1 exemplarily shows, using the installation situation of building "Eckertgasse 10" that measurement points were chosen at the top, the bottom as well as in the middle of the beam head. Additionally, every wooden beam was spot-drilled, to be able to position a sensor in half of the beam's height in the air space between the wood and masonry. To measure the climatic boundary conditions, the indoor climate of the flat resp. the particular room and the outdoor climate on the façade were recorded.

Figure 1. Example of sensor positions at the beams' end for long time monitoring; façade section of "Eckertgasse 10" (above), picture in the ceiling cavity (bottom left), picture of the sensor on top of the beam (bottom right);

There are different installation situations of beam head abutments (Wegerer et al., 2017) and thus also different hygrothermal behavioural patterns which are influenced by constructional parameters. While numerous publications (e.g. Kehl et al., 2013; Guizzardi et al., 2015; Strangfeld et al., 2012) often report on the calculation resp. the simulation of beam heads, there are little findings on the actual behaviour of wooden beam bearings in practice, especially after a retrofitting process.

The fundamental aims of this research paper consist in examining a sufficiently large enough sample of wooden beam heads as well as to achieve a multi-year measurement time. Figure 2 shows the façade of demonstration object “Trubelgasse 8”. In this building, 16 beam heads were equipped with sensors. The measurements on the two demonstration buildings started at construction level and, in the beginning, show the building moisture’s drying-up-process. The continuous, multi-year gathering of data that started in July 2016 gives information about the hygrothermal behaviour during the utilisation phase.

Figure 2. Façade (left) and section (right) of demoobject “Trubelgasse 8” with 16 schematically marked monitored beam heads.

RESULTS

Demonstration building “Eckertgasse 10”

So far, more than 4 years of measurement data are available from this monitoring. Beam heads B1 to B3 are located in the area of an outside wall with interior insulation analogous to the construction in fig. 1. Beam heads B4 to B6 are located in the area of the original outside wall without interior insulation and serve as a reference.

The results clearly show the fluctuations between winter and summer. Furthermore, a steady drying-up-process since the beginning of the measurements is noticeable with all beam heads on the basis of the relative humidity at at least one measurement position. An increase in relative humidity is noticeable with nearly all beam heads during the cold season, which dries up again during the summer months.

To obtain a direct comparison between a construction with and a construction without interior insulation, the measurement data of the sensor positions in the middle of the respective beam head are shown in the diagrams in fig. 3. These positions were made almost identically in all 6 beam heads using drill holes. This comparison shows that in the interior insulation’s area (B1 to B3) critical moisture conditions are reached at the wooden beam heads. Sensor positions on the beam heads bearing in the original, non-insulated construction yield only marginally to barely critical measurement values after the building moisture’s drying-up (B5 and B6). Only B4 shows a higher relative humidity during the winter months.

Figure 3. Temp. graphs (left) and rel. hum. graphs (right) over 4 years after the retrofitting process. The object “Eckertgasse 10” has an inside insulation below the measured floor.

The indoor climate (figure 4, left) shows a moisture load typical for residential use and can be classified into moisture class 3 according to EN ISO 13788.

Figure 4. Left: Indoor climate; right: relation between temperature and relative humidity on the beam ends 1 to 3 (daily average values) and limiting curve according to WTA MB 6-8

The comparison of temperature and relative humidity (figure 4, right) in accordance with WTA MB 6-8 shows that only a few days during wintertime yield critical values. Most of the time there is a low risk of wood rotting because of the drying-up during summer.

Demonstration building “Trubelgasse 8”

In this demonstration building, 16 beam heads are examined after a conventional renovation of the façade without fitting an interior insulation. Three sensors were mounted on each beam head, one in the air cavity facing to the outside and two sensors on the abutment at the contact of wood and masonry. The outside wall has three different thicknesses (see figure 2). As a result, the hygrothermal conditions on the beam head vary highly depending on the storey. Beam heads 1 to 8 are situated in a 60cm thick wall and are covered by 45cm with masonry on the outside. Beam heads 9 to 16 are located in a 45cm thick wall and are covered by 30cm with masonry on the outside. This leads to lower temperature and higher relative humidity at the thinner outside covering. The influence of suspended ceilings is also discernible with this construction. Due to the thermal insulation in the ceiling level, increased cooling of the beam abutments occurs during the winter months. The following evaluation shows results from the 2017/18 winter period. Figures 5a and 5b display data with different wall thicknesses.

Figure 5. Measurement results at the three positions of the beam heads. a) Wall with 60cm thickness, b) wall with 45cm thickness. The object “Trubelgasse 8” has no inside insulation

on the outer wall below the measured floor. Only a suspended ceiling decreases the temperature of the beam end.

DISCUSSIONS

The combination of long-term measurement and a greater sample size of examined beam head details provides new findings on the functional efficiency and durability of current renovation methods. Most Wilhelminian style houses are over 100 years old and virtually no cases of damage on wooden beam ceiling abutments are known. However, renovations and thermal improvements of the building envelope, especially the fitting of more airtight windows, the mounting of an interior insulation system, or the installation of a suspended ceiling filled with mineral wool change the indoor climate and the hygrothermal performance of the outside wall. The measurement results show that certain renovation measures require detailed planning to minimise the risk of damage of the improved construction. Earlier research has shown the behaviour of wooden beam heads with a retrofitted interior insulation based on concrete examples of damage or case-specific hygrothermal simulations. This research paper's results are to emphasise the importance of monitoring and sample size, especially when particular renovation methods, e.g. an interior insulations, are planned. Additionally the findings show that the renovation measures used in the demonstration objects do not put the durability of the existing construction at risk when the building moisture may dry up and the room climate corresponds to average usage.

CONCLUSIONS

The results provide important feedback for the planner and the developer of the demonstration buildings presented. The long-term studies prove the well-tried constructions' functional efficiency and allow an apportionment on the developer's other renovation projects.

The monitoring results are important validation data for current laboratory tests, which are carried out on a true-to-life sample wall with ceiling-to-beam connection in a double climate chamber. The aim of further laboratory tests is to closer examine the beam head detail on the sample wall and to develop accompanying measures, e.g. a targeted tempering of components for constructions with interior insulation.

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