Inside thermal insulation for historical facades

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ABSTRACT: The development of thermal insulation systems with effective physical moisture protection is an important part of research at the Institute of Building Climatology at the Dresden University of Technology. The use of extensive measurement technique enables the monitoring of the hygrothermal effects of energetic retrofitting measures. Additionally the validation of the physical models and simulation codes developed at the institute for the coupled heat and moisture balance of building constructions becomes possible.

Selected results for buildings in Dresden, Senftenberg, Nuremberg, Ebersbach (East Saxony), and Edemissen (nar Hanover) are presented in this contribution.

1 THERMAL RENOVATION OF BUILDINGS WITH WORTH-PRESERVING FACADES

In the cases described in this paper insulations on historical facades without vapour retarder have been investigated. Capillary active insulation materials can transport occuring condensate and built-in moisture away from the potential condensation layer to the warm side of the construction, thus keeping the moisture content of the original construction within safe limits.

1.1. "Gründerzeit"-house Dresden

The facade of the “Gründerzeit” test building (fig. 1) is typical for a large number of buildings. The material used for the inside insulation is capillary active calcium silicate. The complete renovation and the installation of the measurement equipment were carried out in 1996.

The hygrothermal processes in the investigated outside walls of the ground floor, the first floor and the ventilated yardside facade were numerically simulated using the code DELPHIN with the measured climatic boundary conditions (Grunewald, 1999).

The comparison between measured data and the calculated temperature and moisture fields is shown for the wall in the ground floor (comp. Häupl et. al., 1999). Fig. 2 shows the application of the sensors, Fig. 3 and 4 contain the temperatures and relative humidities in the layer between old inside plaster and the coupling mortar of the insulation board. The correspondance between the measured and the calculated values can be identified as very good over the investigated time frame of five years. Solely at the turn of the year 1996/97 and in December 2000 some condensate occurs. From the temperatures and the heat flux a

Fig. 1. Street facade of the "Gründerzeit"-house in Dresden

U-value of 0.64 W/m²K results. The heat loss of this facade was reduced by approximately one third.

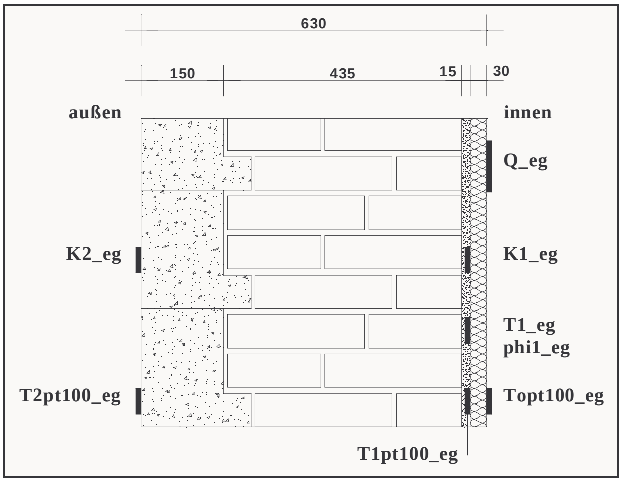

Fig. 2. Wall construction and sensor location in the ground floor of the test building in Dresden

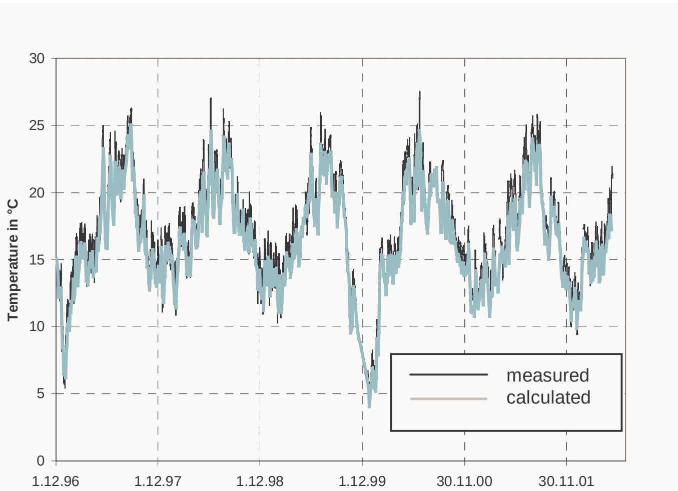

Fig. 3 Measured and calculated temperature between old inside plaster and coupling mortar, time from Dec. 5, 1996 to June 11, 2001

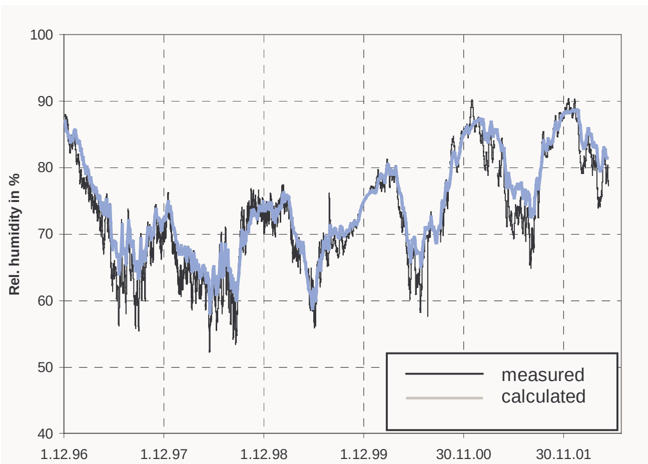

Fig. 4: Measured and calculated relative humidity between old inside plaster and coupling mortar, time from Dec. 5, 1996 to June 11, 2001

1.2. Renovation of the buildings "Bahnmeister-gasse" in Senftenberg

The thermal renovation of the outside walls at the testhouses "Bahnmeistergasse" in the city of Senftenberg (fig. 5) was performed by the installation of seven different inside insulation systems. Capillary active Calcium silicate, mineral foam, cellulose fibre insulations as well as polystyrene, gypsum and composite boards were used. The measurement and numerical investigation has been carried out since summer 2000 (Häupl et.al. 2001).

Fig. 5. Test building in Senftenberg

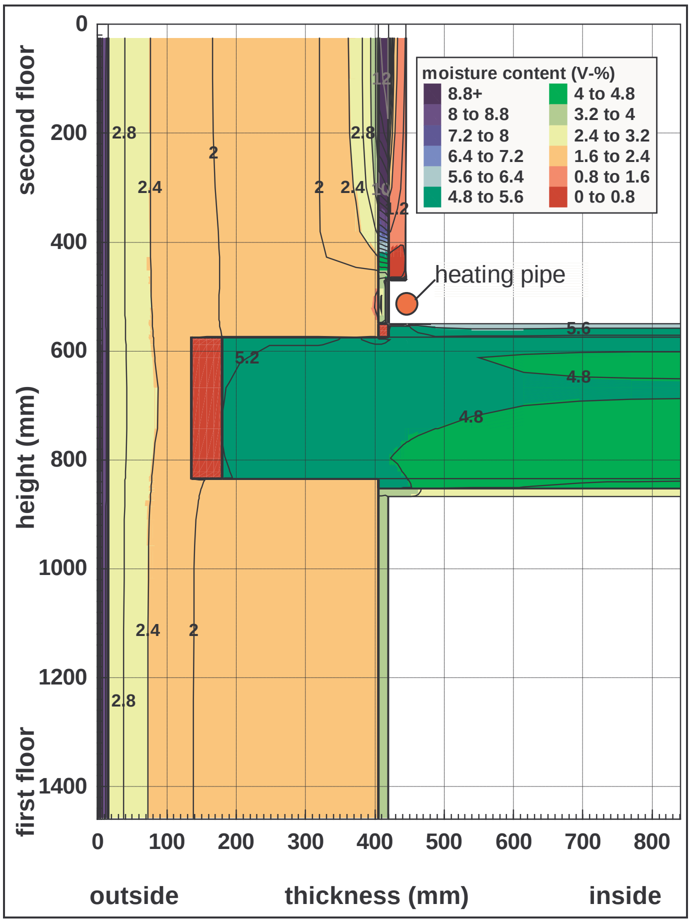

Fig. 6. Senftenberg: Moisture field around the wooden beam head with calcium silicate inside insulation and heating pipe

Meanwhile the material properties of all used building materials are being measured by standardized laboratory experiments (eg. suction curve, sorption curve, water vapour diffusion, comp. Plagge et. al., 1999).

For a successful, damage-free renovation the consideration of thermal bridges and connection points is important. In this building the influence of the room climate and heating pipes on the moisture balance of four timber heads is monitored. One calculated moisture field on February 19, 1999 can be seen in fig. 6. In fig. 7 the measured relative humidity in the air space at the front of the wooden beam are confronted with the simulation results.

Fig. 8 contains the same comparison for the wood moisture content at the measuring point HFBK1.2, which is located approx. 12 cm from the outer beam head. The shown results of measurement and simulation correlate quite well and show safe moisture values for the time frame so far measured.

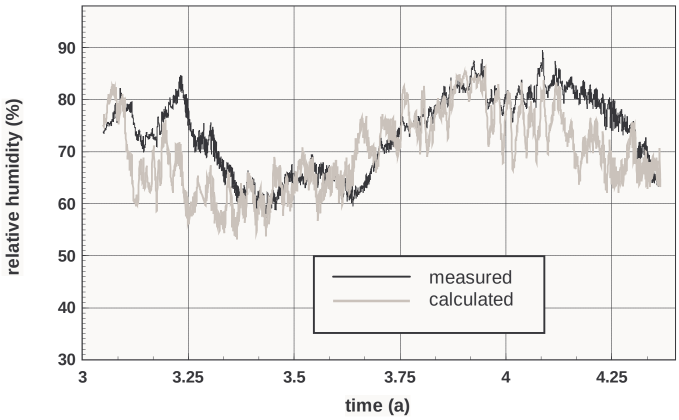

Fig. 7. Measured and calculated relative humidity in the air space at the beam head with heating pipe, Jan. 19,1998 to May 5, 1999

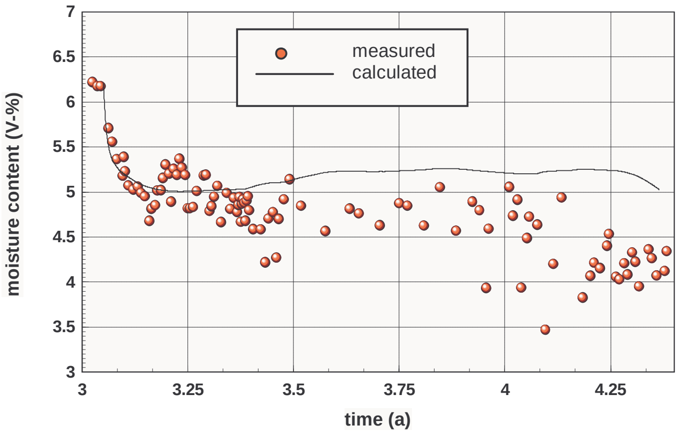

Fig. 8. Measured and calculated wood moisture content 12 cm from the beam head with heating pipe, Jan. 19,1998 to May 5, 1999

1.3. Herrenschiesshaus Nuremberg

The so-called Herrenschiesshaus Nuremberg (fig. 9) contains a public educational centre with conference and office rooms. Together with the Nuremberg Building Department in the summer 2001 two rooms, one office and one conference room, with massive sandstone outside wall were renovated as an example project.

Fig. 9. Herrenschiesshaus Nuremberg

Additionally to making visible the original wooden beam ceiling and the installation of a new floor, an inside insulation of calciumsilicate was attached to the outside wall. The thickness of the in-sulation is 50 mm, in reveals and window niches 20 mm. Parallel a measurement system was installed in each room: in the conference room at the wall between two windows, in the office room in the corner area. Surface and layer boundary temperatures, relative humidity, heat flux as well as outside and inside climate in both rooms are being measured in 30 min intervalls.

With the measured boundary conditions the heat and moisture balance of the walls is numerically reproduced. The comparison of the measurements and the simulation is shown for the relative humidity at the cold side of the insulation in fig. 10. Due to the infrequent use of the office room under low moisture loads the relative humidity of the inside air is as low as 25...35%. Therefore behind the insulation no condensate occurs, though the temperature decreases down to 4°C. Thus, the capillary properties of the insulation material are not exploited.

To demonstrate the usability limits of the wall construction, sample calculations with a constant inside relative humidity of 60% and 70% are shown in fig. 10 and 11. The actual climate

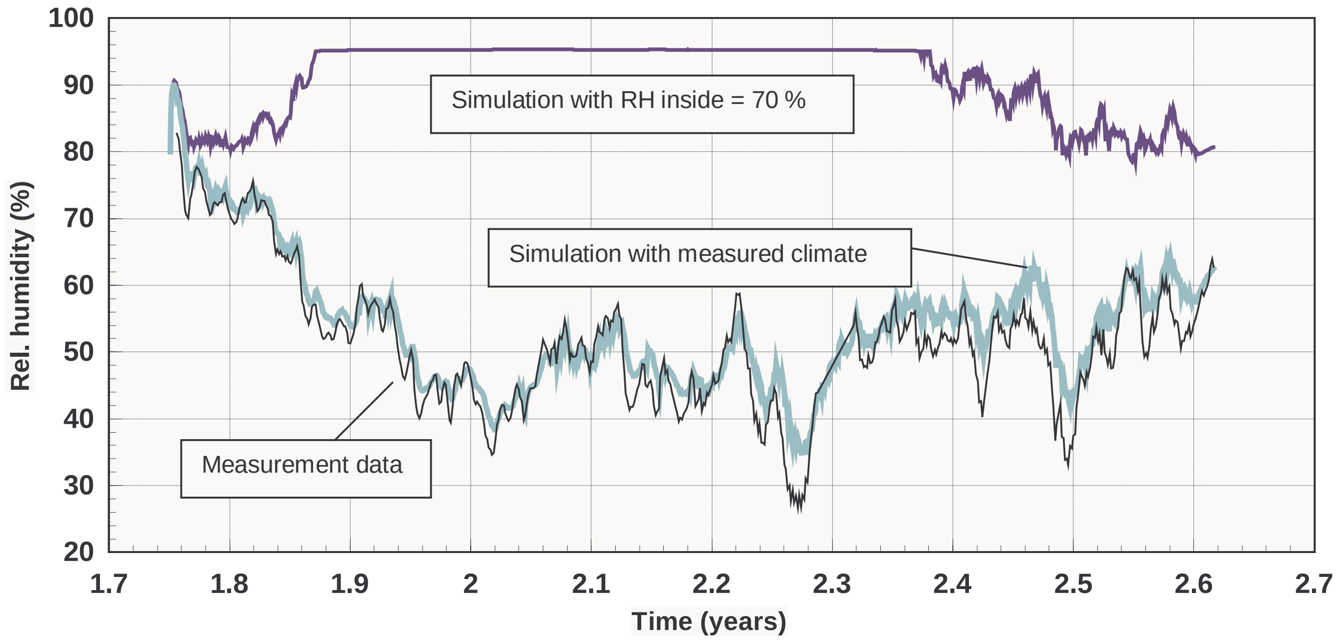

Fig. 10. Herrenschiesshaus Nuremberg: Measurement data and simulation of the relative humidity between insulation and original wall, starting from the application of the insulation boards

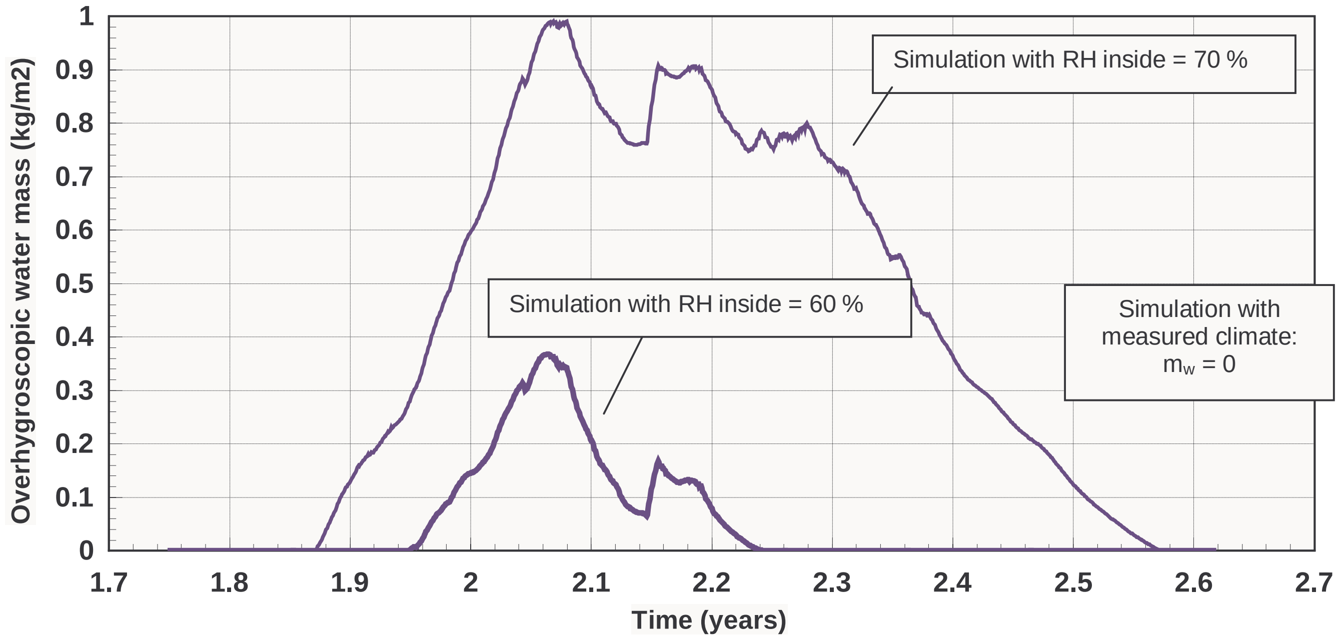

Fig. 11. Herrenschiesshaus Nuremberg: Overhygroscopic water mass in the construction for several indoor air humidities

produces no condensation water, from a constant 60% inside relative humidity during the cold period 0.36 kg/m² would result.

Only with a constant $RH_i = 70\%$ for the whole winter the condensation period starts in November and lasts until May, so that the allowed maximum condensation mass of 1 kg/m² is reached. This shows the significant reserve of the capillary material properties. For the renovation of this building a prize of the "Bund für Heimat und Umwelt" (Association for Country and Environment) was awarded.

1.4. Framework house in East Saxony

At a 200 years old framework house in East Saxony building physical measurements were performed from 1995 to 1999. Eight different inside insulation constructions were tested at the massive wooden wall in the ground floor. In the framework wall of the first floor a new filling of light clay mortar was installed in three framework fields (fig. 12) and provided with inside insulations of mineral wool and calcium silicate boards (Fechner et. al., 1998).

Fig. 12. Installation of the new framework filling in the test building in East Saxony.

In the remaining area a calcium silicate insulation was investigated with the original straw loam filling.

From the numerous results, the effect of the capillary activity of an inside insulation shall be presented with the last alternative.

During the measurement time the building was not inhabited. Thus, the inside climate could be regulated to critical values (20°C, 60...65% during the heating period). With the measuring equipment the moisture content in the framework beams could be countinuously measured and compared to the simulation results. Both measurement and calculation (fig. 13) show maximum values of up to 10 Vol%, this is approximately equivalent to the critical wood moisture content of 18 Mass%, above which a risk for the wood can be expected.

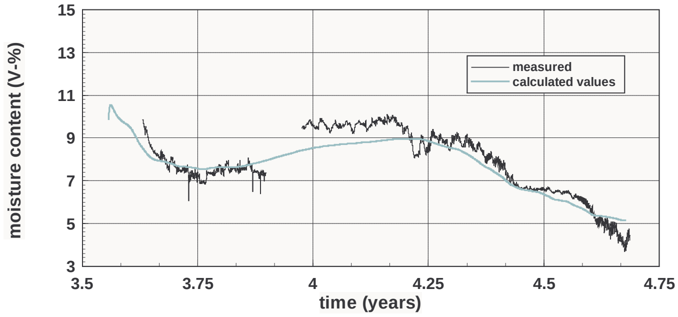

Fig. 13. Measured and calculated moisture content in 13mm depth in the wooden beam (calcium silicate insulation with straw loam filling)

For a quantification of the capillary effect of the insulation material a simulation of the moisture performance shall be presented with and without the capillary properties using the in-situ measured climate data. In fig. 14 (real capillary activity of all materials) the built-in moisture of the board installation can dry out relatively quickly, and the condensating moisture during the next winter period is transported to the warm side of the construction. If the capillary properties are not regarded – according to the current moisture protection codes – the built-in moisture cannot dry out before the condensation period starts (the installation took place in late August), and a moisture content of more than 45 Vol% occurs in the insulation material, leaving the loam plaster wet (moisture field in fig. 15).

The direct comparison of the overhygroscopic moisture content for these two cases in fig. 16 underlines these statements. The incomplete drying of the initial moisture leads to a water mass of 6 kg/m² in the first winter. During the second winter, when water penetrates only in vapour form from the inside, still significantly over 2 kg/m² occur. Taking into account the real material properties, the drying takes place quickly, and the construction contains only a maximum of 0.6 kg/m² in the second heating period.

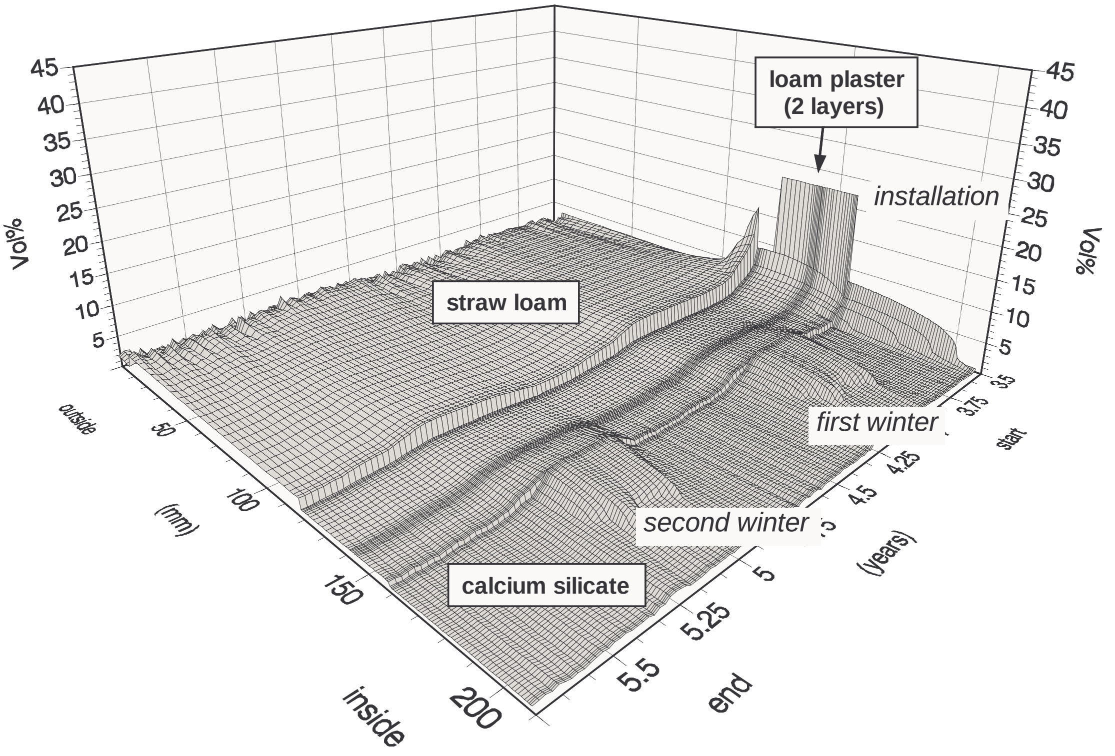

Fig. 14: Water content profile in the center of the straw loam field (one-dimensional simulation) with measured capillary conductivity for all materials

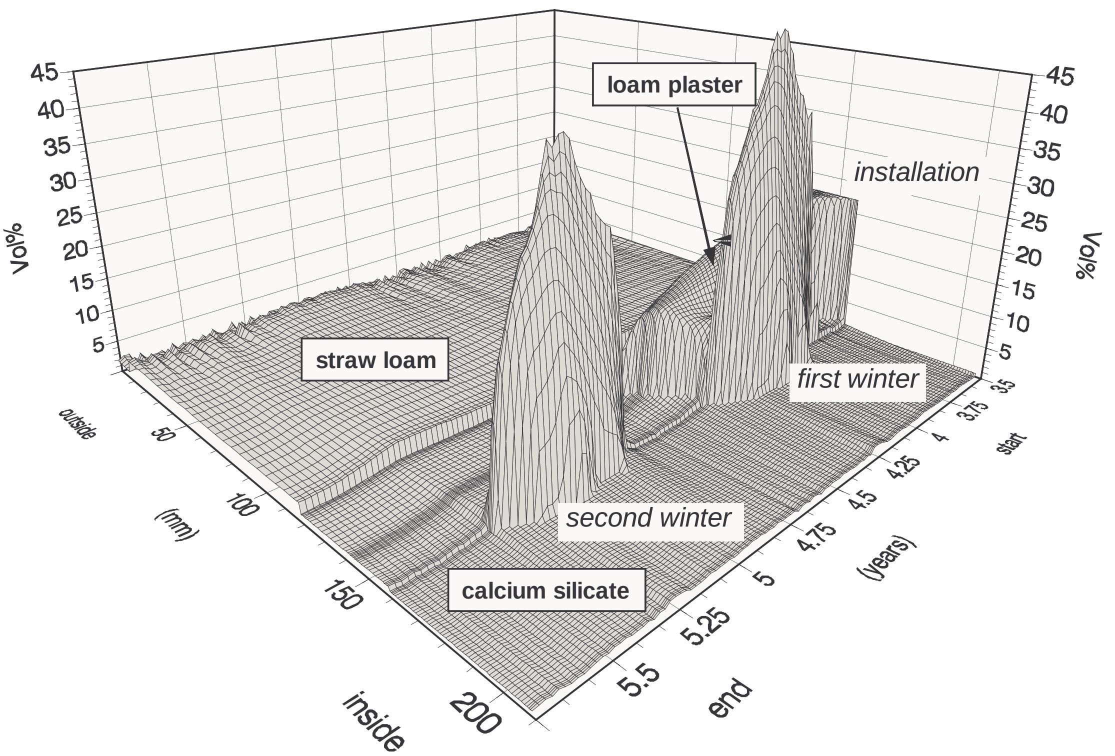

Fig. 15: Water content profile in the center of the straw loam in time (one-dimensional simulation) without consideration of capillary forces of all materials

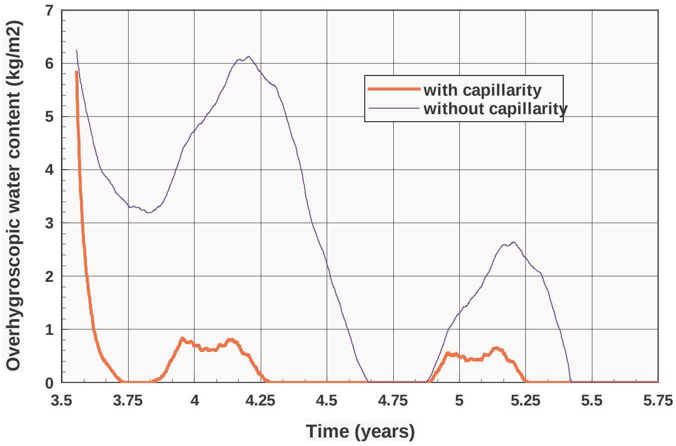

Fig. 16. Test building in East Saxony: comparison of the integral overhygroscopic water mass in the construction with and without consideration of capillarity

Since 2000 measurements in an inhabited framework house with inside insulation in Edemissen near Hanover (fig. 17) are conducted, to a certain extent as a continuation and application of the works in East Saxony. In this building sensors in the outside wall of two bathrooms (north and east side) and in one living room were installed. Additional to temperatures, heat fluxes, and relative humidities within the construction, moisture contents are measured in a number of wooden beams. Hitherto, the comparisons of the measurements with the simulations show good correspondance.

Fig. 17. Test building framework house near Hanover, view from north-east

CONCLUSIONS

The presented building physical measurements demonstrate the function of several inside insulation systems at a number of different outside wall constructions. The application of capillary active inside insulation materials proves advantageous for the drying process of potential built-in moisture as well as for the limitation of the condensation amount during winter. The U-value of the building walls could approximately be halved in the presented cases without the necessity of vapour barriers.

All measurements were reproduced by simulations with good correspondence using the in-situ measured hourly values of inside and outside climate.

REFERENCES

Grunewald, J. 1999. Mass and Energy Transport in Porous Media – Thermodynamical Identification of Driving Potentials. Int. Zeitschrift für Bauinstandsetzen und Denkmalpflege, 5. Jahrgang, Aedificatio Publishers, Heft 2, pp. 113-142,.

Häupl, P.; Grunewald, J.; Fechner, H. 1999. Moisture behaviour of a "Gründerzeit"-house by means of a capillary active inside insulation. Proceedings of the "Building Physics in the Nordic Countries 1999, pp. 225-232, Göteborg

Häupl, P.,Stopp, H., Petzold, H. 2002. Thermische Sanierung von Fachwerkwänden mit kapillaraktiver Innendämmung. In: Fachwerksanierung nach WTA, Band. 2, Fraunhofer IRB Verlag

Fechner, H., Häupl, P.; Martin, R., Neue, J., Petzold, H. 1998. Thermische Sanierung von Fachwerkbauten mittels Innendämmung - ein Vergleich zwischen Messungen und numerischer Simulation, Bauklimatische Hefte, Heft 5, TU Dresden

Plagge, R.; Grunewald, J.; Häupl, P. 1999. Simultaneous determination of water retention characteristic and moisture conductivity using instantaneous profile techniques, Proceedings of the "10. Bauklimatisches Symposium", pp. 433-444, TU Dresden