Investigation of the hygrothermal performance of wooden beam ends embedded in inside insulated outside walls

H. Stopp & P. Strangfeld
Department of Building Physics, University of Applied Sciences FH Lausitz, Germany

Abstract

The inside insulation has been investigated in the past by means of scientific institutions as a necessary method in connection with the thermal improvement of worth-preserving facades of architectonic heritage. In the case of fair faced brickwork it is established on homogenous areas of the wall, for instance as a variant of capillary active systems or as a classical version with a humid-dependent vapor barrier. With regard to the insulation of special details, e.g. embedded wooden beam ends within areas of outside walls, the opinion of experts differs considerably. Both the total ventilation of the beam ends and complete air tightness are proposed. In line with the new European directive on the energy efficiency of buildings, innovative ideas should also be developed in the field of building physics in order to realize the restrictions without damage to building envelope parts. The main point of this paper is the investigation of the hygrothermal situation of embedded beam ends in inside insulated outside walls, dependent on time and climate boundary conditions. The topics are treated by means of in situ measurements in two test houses in the eastern part of Germany under condition of use and by experiments in connection with an erected test stand. A comprehensive numerical simulation of the coupled heat- and mass transfer supports the measurements to reduce the experimental work. In principle there are several options to avoid the effects of the hygrothermal deficiencies of the structure caused or intensified by inside insulation. Hygrothermal effects are quantified and solutions are found for workmanship without damage.
Keywords: wooden beam ends, worth-preserving facades, heating energy saving, hygrothermal performance, damages to structures.

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1 Introduction

In case of worth preserving facades there are some conflicts: for an example on the one hand the changing climate conditions challenge the mankind to develop political strategies and to implement measures that reduce greenhouse gas emissions. Plans of European Member States call for 20% ...40% decrease by 2020. Another key objective, which is linked to the environmental protection, is to make European states less dependent on oil and gas. Current forecasts indicate that without measures this dependency will jump to approximately 70% by 2030. A directive of the European Parliament and of the Council on the energy performance of buildings was published and discussed in the past. The updated regulation came into force in Dec.16th 2002 [1]. The directive should be realized in the member states of the European Union up to 2006. About 41% of the total final energy demand of Europe is used in the residential and tertiary sectors. Space heating is by far the largest energy end-use of households in EU Member States, namely 57%. Therefore the European directive covers four main elements:

-Establishment of a general framework of a common methodology for calculation the integrated energy performance of buildings.

-Application of minimum standards on the energy performance to new buildings and certain existing buildings when they are renovated.

-Certification schemes for new and existing buildings on the basis of the above standards and public display of energy performance certificates and recommended indoor temperatures and other relevant climatic factors in public buildings and buildings frequented by the public.

-Specific inspection and assessment of boilers and heating and cooling installations.

About 32% of the current stock of the 150 million residential dwellings in the 15 old EU Member States was built prior to 1945, about 40 % between 1945 and 1974 and 28% since 1974. An upgrade of thermal insulation regulations and improved efficiency for installed equipment for existing dwellings, bringing them close to current buildings codes, would help to realize an important saving potential, making it a very desirable and in most cases a cost-effective option.

So the directive is explicit valid for existing buildings too. In the face of the low turnover rate of buildings with a lifetime from 50 to more than 100 years it is clear that the existing stock of buildings contains the largest potential for improving energy performance in short and medium periods of time.

On the other hand due to an architectonic heritage the use of a thermal insulation composite system or another outside insulation is not possible. An inside insulation may be an alternative if the hygrothermal and acoustic behaviour is considered. But in regard with the inside insulation of wooden beam ends embedded within areas of outside walls, the opinion of experts differ considerably. For this reason the investigation is to be done both by means of numerical simulation of the coupled heat- and mass transfer included the effects of ventilation and a lot of in situ measurements in test houses under condition of use and by experiments in connection with an installed test stand in a laboratory.

2 Calculation of the hygrothermal performance

Owing to the requirements of the new European directive and to the demand for a comfortable room-climate the thermal insulation of outside walls of existing buildings should be increased. A good solution for homogenous areas in case of worth- preserving facades is the so-called capillary-active inside insulation or a classical version with a humid-dependent vapor retarder [2]. The results of the numerical simulation of the coupled heat and moisture transfer, represented in this paper are carried out by means of the program "Delphin" [3], validated also in international projects.

Fig. 1 represents the moderate moisture distribution by means of a capillary active calciumsilicate inside insulation without use of a classic vapor barrier. This method guarantees the drying out of moisture caused for instance by driving rain at the facades. Owing to the capillary diffusivity function of the material calciumsilicate with a maximum of $10^{-5}m^2/s$ the condensation at the cold site of the inside insulation is limited in wintertime and due to the deleted vapor barrier a sufficient drying out process takes place during summer period.

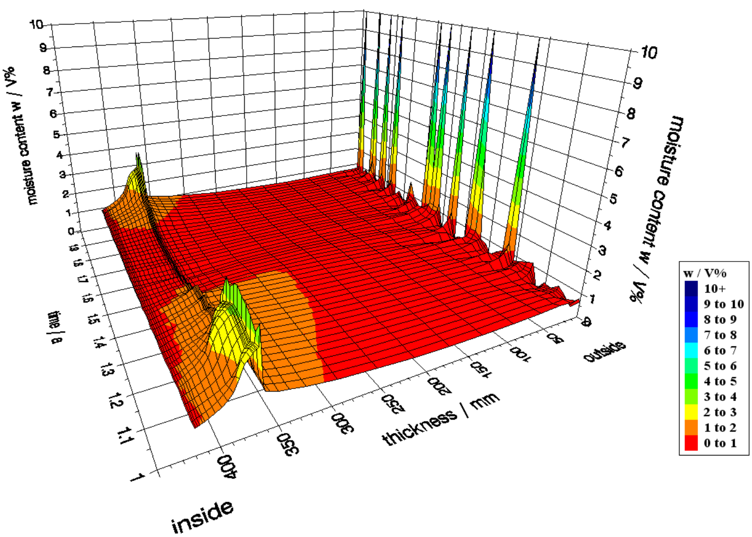

Figure 1: Moisture field of an inside insulated brick masonry wall by 50mm calciumsilicate. Indoor climate: 20°C; 50%. Outdoor climate: TRY Middle Europe, hills, Westside

Embedded wooden beam ends in connection with an inside insulated worth preserving facade can be a hygrothermal problem. A non-reflected application of energy saving directives particularly with regard to the interior insulation can cause defects of restoration. The formulated requirements of the energy directives are raising many questions to the architect, contractor and client of a restoration project. Therefore the purpose of a special recommendation of the

WTA [4] is to provide support in interpreting and applying the regulations (e.g. in case of half-timbered framework the additional thermal resistance of an inside insulation system should be limited to 0.8 $m^2 \cdot K/W$).

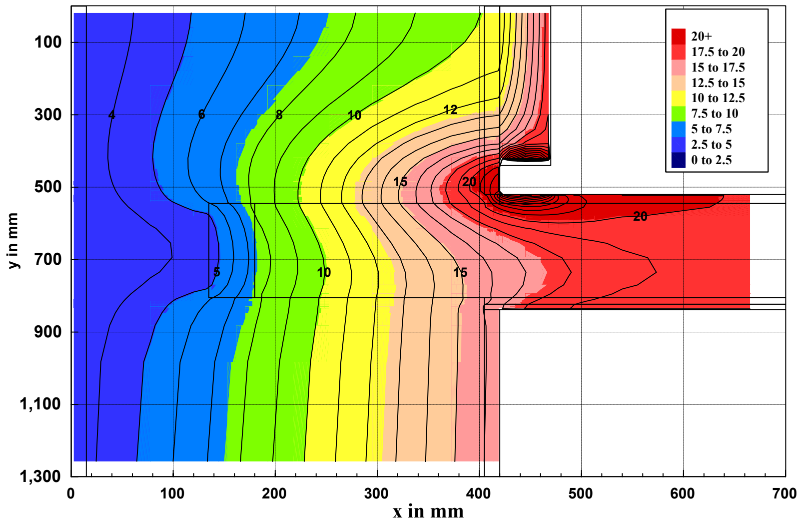

Figure 2: Temperature field Jan. 29th, variant "heating channel", heating mobilized, (air temp within channel: 35°C, partial pressure of water vapor: 1170 Pa), TRY Middle Europe.

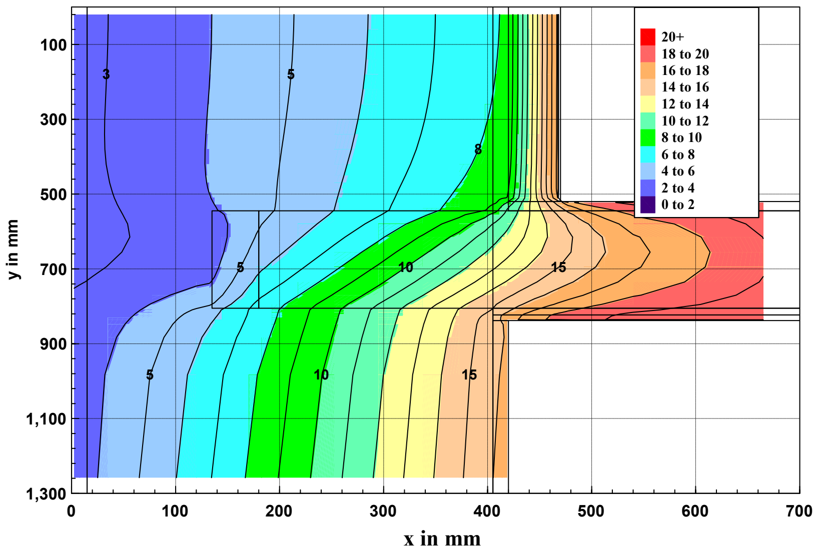

Figure 3: Temperature field Jan. 29th, variant: "complete inside insulation system", TRY Middle Europe.

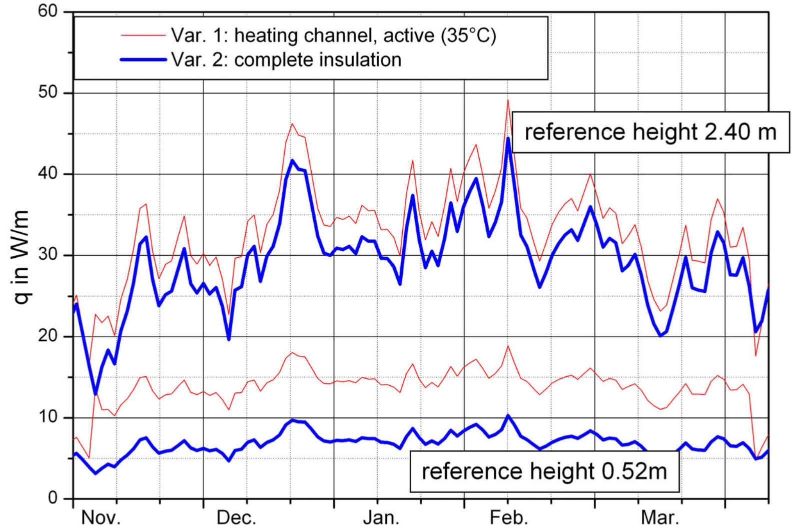

Figure 4: Effect of thermal bridge caused by a mobilized heating cannel, additional heat losses of the wall, related high of wall 0.52 m and 2.40 m, width of wall: 1 m.

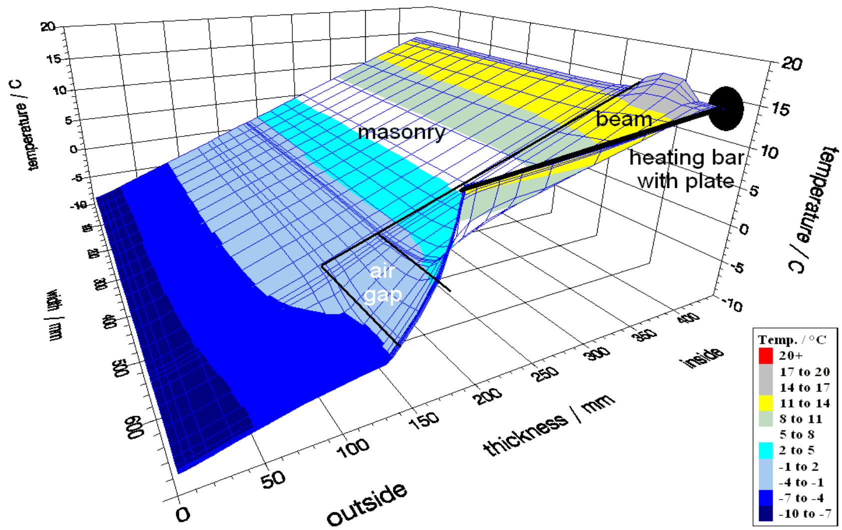

Figure 5: Temperature field of the area of the wooden beam end influenced through a so called passive heating bar (thermal short-circuit by means of the inserted metallic conductor aluminium) Climate boundary conditions: indoor 20°C/50%; outdoor -10°C/80%.

The selected figures 2 and 3 demonstrate the deformation of isotherm-lines by the operating flow pipe and return, installed within a „channel" of the insulation near the floor (the insulating calciumsilicate panel with a thickness of 50 mm is replaced at the bottom for a height of 80mm) in comparison with an inside insulation of an outside wall completely (fig. 3). Fig. 2 shows the positive effect of an operating heating pipe in a channel. The increased temperature of 3 K at the front side of the beam should not conceal the fact that the calculated decreasing of the wooden moisture at the same place amounts to about 1mass% only. The fig. 4 represents the additional heating energy losses caused by the effect of thermal bridge with different reference areas of the wall. In the fig. 5 the shifted temperature field is shown caused by a so-called passive heating bar.

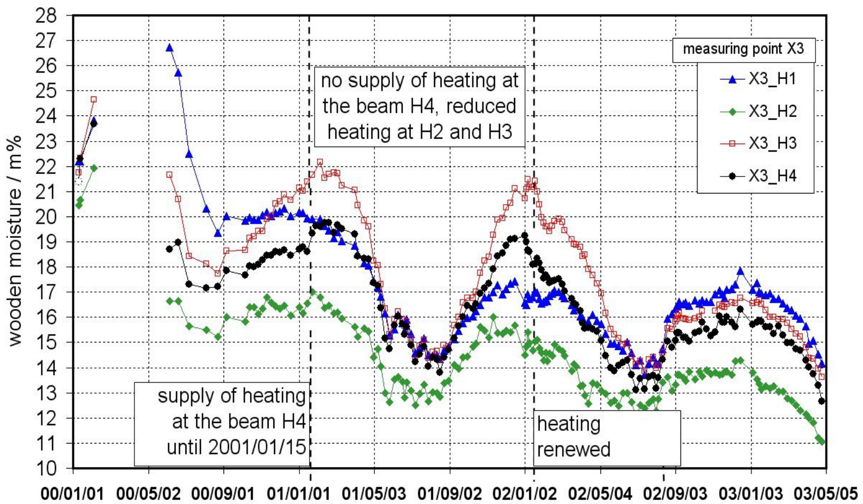

Figure 6: Course of the wooden moisture measured in front of the four wooden beam ends H1...H4 after retrofitting is finished.

3 Experimental investigation

3.1 In situ measurements

The in situ measurements are carried out under conditions of use in a climate of Middle Europe in test houses near Berlin [5]. The courses of the wooden moisture content of four investigated wooden beam ends prove the considerable quantities of moisture built in during the retrofitting activities. They show the long periods of drying out in laps of several years also in case of indoor climate similar to an office, fig 6. The start of the supply of heating at the wooden beam end H4 by means of a lengthened flow pipe with return as a bypass is to recognize clearly. The wooden moisture decreases by 2M% in comparison to a no operating flow pipe (Comment: beam ends H4, H3 and H2 are influenced through the same pipeline of flow and return for the heaters. Only H4 is to separate from the heating energy supply completely – no heater is installed parallel to the pipeline). The reduction of the relative humidity of the air gape surrounding the beam head amounts up to about 10%, fig.7.

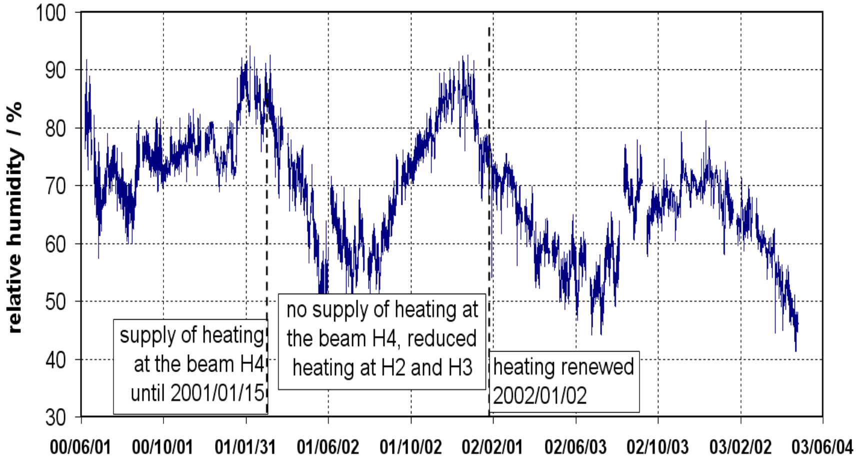

Figure 7: Course of the relative humidity of the air gape in the front side of the beam end H4.

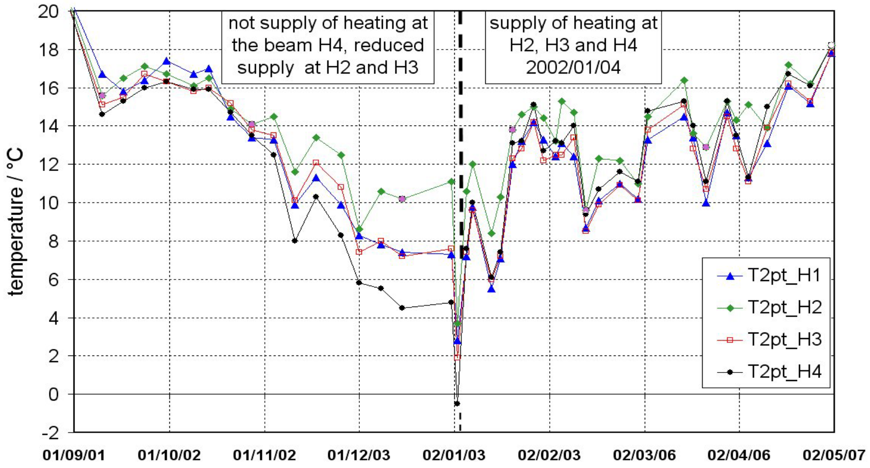

Figure 8: Course of the temperature in front of the four wooden beams ends H1...H4 dependent on the heating supply through the flow pipe and return.

The effect of the additional heating supply through the heating channel to the temperature in front of the beam ends demonstrates fig. 8. After the heating flow to H4 is mobilized (Jan.4th.2002) the differences between the temperatures at the beam ends H4 and H3 are compensated.

Experiments depending on the users activities deal with the influence of the indoor air on the humidity of the air gaps surrounding the inside insulated beam ends. The influence of a natural ventilation by opening of windows or/and doors is an indifferent result in practice and can bring in warm-humid air into the area of the air gaps, fig. 9.

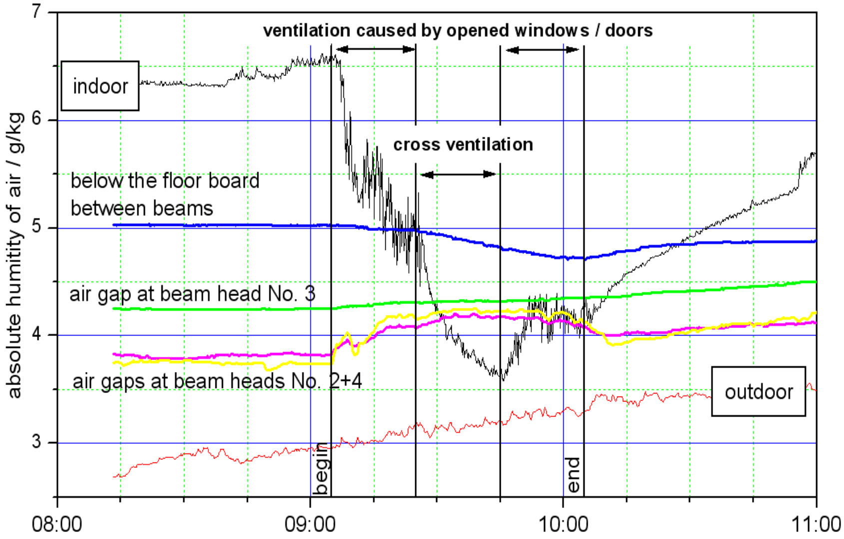

Figure 9: Penetration of indoor air to the front side of wooden beam ends owing to the activities of inhabitants

3.2 Test stand

The effect of an additional energy supply is small in case of a thermal short-circuit of the natural temperature gradients between the indoor and the air gape by means of a good conductor without thermal resistance, e.g. through a metallic bar inserted into the wooden beam end. In opposite to that passive bar the fig. 10 shows the abrupt increasing of the temperature from March 8th in 2003 clearly in spite of the many measuring points at the prepared wooden beam head. The period of heating energy supply of an active heating bar is realized in combination with an underfloor heating.

4 Conclusions

With regard to the hygrothermal performance of wooden beam ends embedded in inside insulated worth-preserving outside walls, some results for practice are represented and evaluated in the following briefly. They are worked out by numerical simulation and measurements under conditions of use.

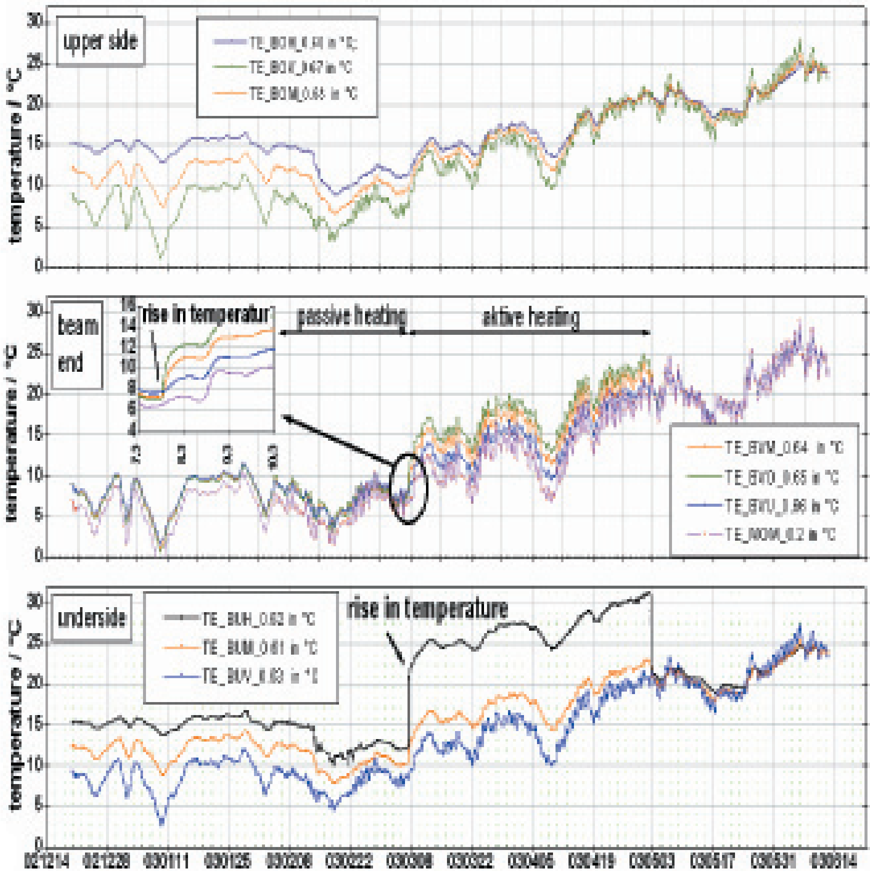

Figure 10: Effect of a so called active heating bar within a wooden beam head mounted in an outside wall of the Building Physics testing floor of the FH Lausitz.

- A supply of additional heat to the wooden beam ends by an aimed conductivity of heating energy including available building components represents the best solution.
- For instance without additional expenses and few effort the heating system's flow pipe and return fitted in a heating channel should be used. The effect of thermal bridges is to neglect.
- The idea of a so-called passive or active heating bar, inserted into the wooden beam end connected with an underfloor heating, is an interesting variant. It should be tested detailed in future.
- Concerning the influence of the natural ventilation on the hygrothermal situation of the air gaps surrounding the beam ends the investigations show that the wooden beam ends are individualists.

- In connection with a bigger stock of existing buildings of an increasing European Union the topic provides an option for the preservation of a lot of the building heritage in the new eastern countries. The thermal insulation of outside walls with worth-preserving facades and embedded wooden beam ends can be improved without damage.

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