

Insulating timber-framed walls of historical buildings using modern technologies and materials

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Abstract

Buildings made with the use of timber-framed construction are one of the oldest types of housing in Europe. Some of them date back even to the 12th century. Those which have survived are the historical heritage of building art and architecture of that time, decorating landscapes and evoking the spirit of a bygone era. The process of repair and adaptation of this kind of monument is complicated and requires a very careful analysis of timber-framed structure and materials. Any repair or improvement should be devised to minimize the risk of damage to the historic fabric. An important aspect which requires attention is an improvement of the thermal insulation of external walls, comfort for inhabitants, and the energy efficiency. Timber frames are characterized by heterogeneous material being used to build the walls (especially many sorts of filling e.g. brick, clay from the chaff), so it is particularly important to properly select materials, technology, and mounting method for the insulation. Old buildings constitute environmental risk of vapor condensation, which can lead to destruction and decay of walls, wooden beams moistness and microbiological corrosion. These issues can be easily observed by performing an analysis of heat and moistness of an external wall. Modern technologies, building materials and innovative ideas may all contribute to achieving a compromise and a reasonable result which ensures convenient usage of the building while maintaining its historic values such as wall paintings, stamps, etc. It is also worth taking a closer look at some of the solutions using passive house standards in the protection of historic timber-framed buildings.

Keywords: insulation, historic buildings, modern technologies, wooden frame construction, methods of prevention.



1 Introduction

From the technological perspective, structures built in a wooden frame are very distinct. Over the centuries such structures have been used for the construction of residential houses, castles, town halls, barns and other kinds of buildings. The extensive use of this type of construction was possible due to high availability of natural building materials, such as: wood, clay, straw, reed, brick and stone. Thanks to refurbishments and renovations being carried out, some of the buildings have survived through the centuries [1]. In order to provide its inhabitants with the appropriate thermal comfort, ensure technical standards are met and insulate the external walls; the buildings are subject to renovation and thermal insulation. As works carried out in premises reveal, renovation is often a compromise between the desire to preserve historical appearance of a preserved facade and adjusting it to the modern utility and thermal standards [2].

2 Characteristic timber-framed walls

Skeletal walls – timber-framed are built with the use of clay with straw or reed, brick, and sometimes stones as a filler. Brick field may get destroyed in the course of operation and be covered with plastered and whitewashed. A characteristic feature of this type of wall constructions is heterogeneous barrier that affects the uneven distribution of temperature and water vapor in a chamber. Building works carried out in an unprofessional way or erroneous application of thermal insulation may lead to increased humidity and building damage, not to mention the damage to historic value. Thus, considering the above, the most appropriate solution would appear to be to apply the thermal insulation on the inside. However, this would not be correct in terms of building physics and would create problems with moisture. Thermal resistance of insulation placed on the inside causes a drop in temperature barrier and thus increases the likelihood of condensation plunge diffusing through a barrier of steam. The consequence of this phenomenon may be a frost wall, which in turn, in a short period of time, leads to its destruction. Insulation should be properly prepare before starting work on it and eliminate the destructive influence of factors which include water, moisture and damage, cracks and defects in the construction of a wooden object. Most objects do not have horizontal insulation to protect against rising damp moisture and the negative impact of rainwater. To minimize this problem, and provide a solid foundation of common ground horizontal beams were laid on stone or brick pedestals. These solutions, however, do not fully have achieved the desired effect. The walls in timber framing, depending on the season absorb and emit moisture to the outside and the inside. In addition to the plinth area exposed to moisture sore point is the combination of wood frame with filling, due to the heterogeneity of materials which respond differently to temperature, humidity and moisture barrier by changing its physical and mechanical properties. With the increase of moisture in the partition increases the risk of microbiological corrosion and mold growth. Remember also to carry out thorough examination and repair of wooden bearing structure by replacing damaged parts, including

supplements, strengthening connections carpentry, impregnation and protection against corrosion and microbial and insect seal calls to contacts between the beams. The last aspect is so important because it showed that the joints between beams collected air acts as a thermal bridge, causing cooling of the outer barrier.

3 Technologies and materials of insulation timber-framed walls

According to a German study [3] carried out for an external partition of a thickness of 14 cm, in order not to be followed by a periodic condensation of water vapor, thermal resistance of the barrier must have a minimum value of $1 \text{ m}^2 \cdot \text{K} \cdot \text{W}^{-1}$. Among traditional materials the ones closest to achieve this value, apart from wood, are clay with wood chips or sawdust. For this material of the indicated thickness thermal resistance is at the level of $0,5\text{--}0,7 \text{ m}^2 \cdot \text{K} \cdot \text{W}^{-1}$. In bad weather conditions it is possible that periodic external moisture occurs which may get further worsened by external factors such as driving rain. Calculations indicate that it is the thickness of the insulating layer that determines the moisture barrier. Analysis showed that the use of mineral wool insulation with a thickness of 3 cm does not exceed 20% moisture storage timber (which in the long run leads to the occurrence of biological corrosion). To reduce the amount of water vapor diffusion a vapor barrier with a limited diffusion resistance can be applied on the inside. With this solution during the periods of high humidity drying from the inside is possible [2].

An even better solution, as long term research proves, is the use of adaptive film humid characterized by a variable diffusion resistance depending on the humidity of external environment. As demonstrated by the measurements, the use of this type of film ensures the maintenance of moisture storage timber at a constant level of up to 20%. The use of insulation from the inside causes the septum to move into a low temperature zone, and thus, wood-framed wall construction elements would be located in the zone of freezing. For this reason it is necessary to limit the thickness of thermal insulation for Polish and German climate conditions to 5–6 cm. Application of the solution given above obliges us to do very tight vapor barrier. Given that the wall frame is continuously under some operations, including changes in humidity, temperature and load, in the course of usage the continuity of tight vapor barrier can be damaged. Therefore, it is quite common to apply solutions that are designed to increase the thickness of the outer barrier by using insulating materials with lower thermal resistance and vapor permeability at the expense of more usable space. This solution allows for an even distribution of the increased resistance of the outer barrier and enables a very efficient drying out and breathing of the barrier. As research shows, half-timbered not insulated construction effectively dries the moisture gained from driving rain [2].

Resistance of the outer wall can be raised by increasing its thickness. Such solution may be implemented by insulation with the foundation layer of light loam (clay with saw dust) which plays the role of a type of insulation with a thickness of about 10–15 cm. Rail scaffolding, consisting of vertical bars spaced



every 30 cm is impaled to a system of horizontal beams. Then, planking of a width equal to the thickness of the insulation is screwed to the vertical bars. It is of high significance that the two processes are conducted simultaneously and the horizontal spacing between the boards is maintained [4]. The resulting grid is filled with light clay (clay with straw) used as an insulation material and then tamped to get a tight, compact layer (Figure 1). Having built the above mentioned layers of the formwork reed mat is mounted to the planking, which constitutes reinforcement for two layers of internal plaster. Insulation prepared in this way dries out within 4 to 12 weeks, depending on the season. This solution helps to reduce heat loss through the outer barrier and ensures a systematic drying of compartment [1].

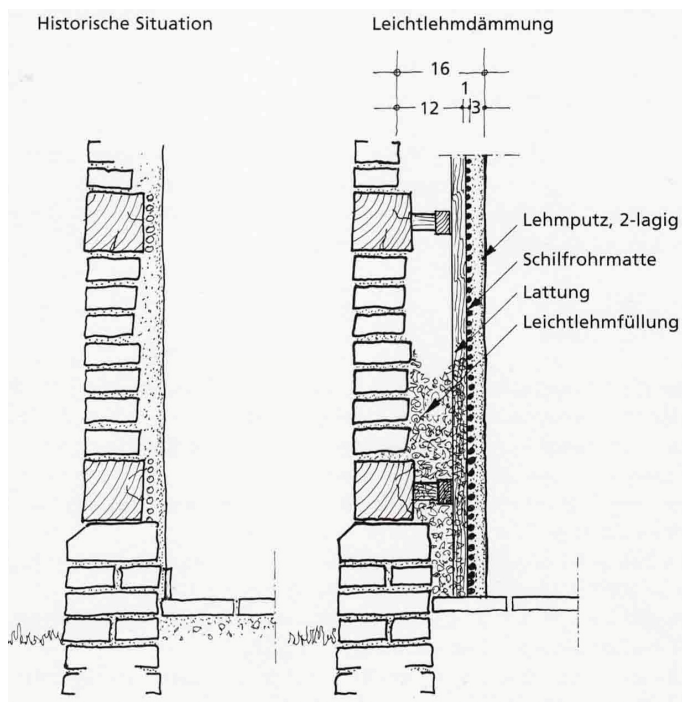


Figure 1: Section through the wall with using light clay as insulation [1].

Another common solution, based on Cellco – a modern product made from natural materials, created specifically for the purpose of inside insulation. It is composed of a mixture of materials: clay, cork, straw and diatomaceous earth. This material is characterized by similar properties as lightweight clay mentioned above. Construction, grate and laying method is analogical to the solutions used with light clay. A 5–8 cm layer of insulation is placed inside the wooden grate. Once it has dried out (which takes 4–6 weeks), lime mortar or clay is applied on

the surface. Please note that when crossing the ceiling it is essential to remove the form work from the existing floor to ensure continuity of internal insulation [1]. Another method is to perform internal insulation with the use of Tektalan stacking plates. These are multilayered composite panels with a core made of non-combustible rock wool fibers perpendicular to the surface. The external layers are tied with magnesite wood wool and impregnated with anti-mold agent. Most commonly used are warm plates of a thickness of 5 cm that are additionally mounted to the beam anchors (Figure 2).

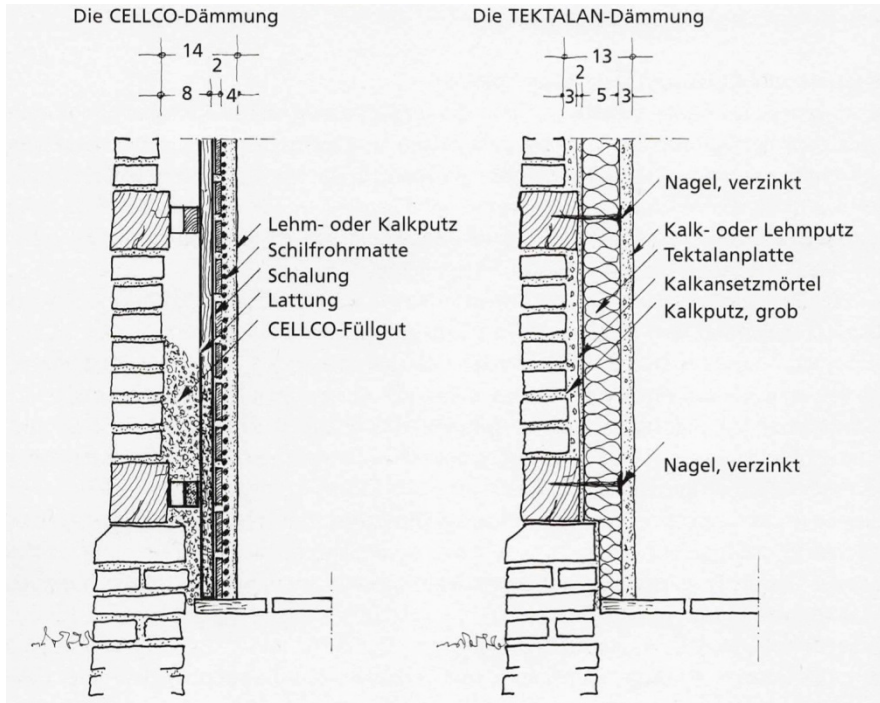


Figure 2: Vertical section through the wall with Cellco as insulation [1].

The plates increase thermal resistance and thanks to the use of the board core with mineral wool they are breathable [1]. To isolate the outer barrier from the inside panels of wood fiber are used. The method of installation and mounting is similar to the plate Tektalan, with the difference that no mechanical fasteners are used. Insulation panels made of wood fiber are breathable, resistant to moisture and capillarity. They constitute a suitable material for inside insulation of the wooden walls, especially in combination with clay materials. They are available in thicknesses of 1–6 cm [5]. However, for the purpose of inside insulation it is enough to use plates with a thickness of 4–5 cm. This solution is an interesting alternative to clay as it does not absorb moisture and in the construction process it requires only a small amount of water [1].

Light brick clay with straw is a modern ceramic product on the market. The high content of straw fiber ensures isolation. When building up walls from the inside it does not require much water and as a result dividers dry out faster and the technological process is shorter. It is placed on the clay mortar, thus isolating the material from an existing partition (Figure 3). As far as disadvantages of this solution are concerned, a relatively large thickness of the insulation layer is required, using up potential usage space. The requirement is caused by a low coefficient of λ . When installing heavy internal isolation it is worth to consider strengthening the ground and sometimes even laying the foundation for raising walls and appropriate insulation of the joint between them [1].

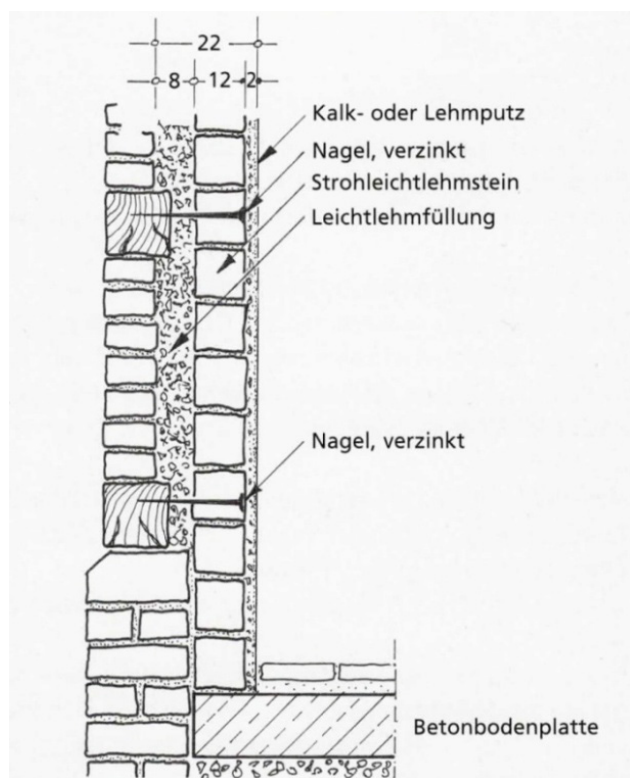


Figure 3: Vertical section through the wall with light clay brick as insulation [1].

Another possible solution is the building up walls on the inside and providing thermal insulation in such a way that the insulation is placed between the existing walls and the newly constructed ones. Between the existing wall and the insulation ventilation voids need to be placed. In this arrangement, the wood framed construction functions as a three-layer wall [1] (Figure 4).

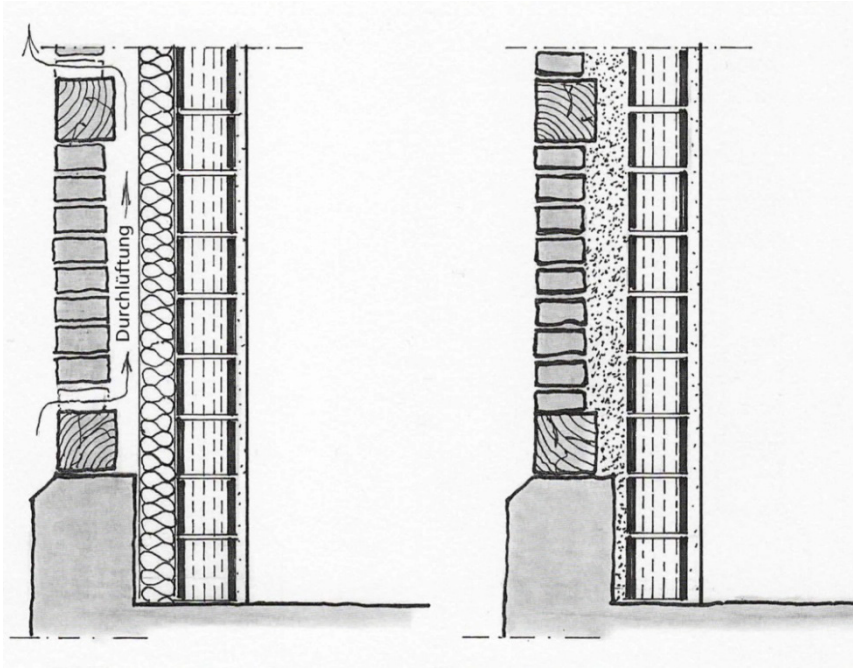


Figure 4: Section through the wall with new construction and insulation [1].

When we are dealing with the renovation of an antique complex, with reinforcement and replacement of corroded beams, timber-framed structures and fill, it is possible to use modern building materials, which are a much better protection against significant heat loss compared to brick or clay. Such materials include cellular concrete, which due to its low weight (the weight of the material does not strain the historical construction of static object) has a low coefficient of heat transfer and high porosity. The way it works is based on the principle of accumulation of moisture inside pores during the fall and winter seasons and its disposal in the spring and summer seasons [6]. A number of objects made with the use of this technology leads to the conclusion that its application could be implemented in buildings with wooden frame. Joints between the blocks, made of mineral wool or expanded polystyrene (Term wall system), placed on a warm mortar have the effect of reducing heat loss [7]. A new product, which affects the reduction of heat transfer to the barrier and reflects red radiation from its inner layer is Aero-Therm. It is a thick substance of the consistency of a paint which consists of Aerogel and 3M glass microspheres. In order to build protection against heat loss, the substance is applied to the inner side wall as a barrier layer with a thickness of approximately 1.0 mm. Thanks to its versatility it can be used not only for walls but also on the floors, ceilings and roofs [8]. Currently there are attempts to design a material based on Areogel, which could be used on the

outside compartments. The way it works could be compared to a shell that protects against heat loss in both space and barrier.

4 Conclusions

In recent years there has been a rapid development of research investigating the subject of thermal insulation and insulation systems that could be used in historic buildings. Thanks to the development of science, nanotechnology – as described in the last solution referred to new materials which could help to protect historic buildings are produced. All kinds of studies contributing to the growth of knowledge in this endeavor allow us to hope for times when historic buildings will meet the heat and moisture standards without any damage to their historic and aesthetic values.

References

- [1] Lenze W., *Fachwerkhäuser. Restaurieren – sanieren – modernisieren*, Fraunhofer IRB Verlag, Stuttgart, pp. 52-129, 2002.
- [2] Radoń J., Künzel H., *Problemy ciepłno-wilgotnościowe przy renowacji ścian budynków z muru pruskiego*. Architectura 5 (1): pp. 45-53, 2006.
- [3] WTA-Merkblatt, *Bauphysikalische Anforderungen an Fachwerkfassaden*. 8-1-96, 1997.
- [4] Hähnel E. *Fachwerkinstandsetzung. Ein praxishandbuch*. Berlin HUSS-MEDIEN, 2003.
- [5] www.knauf.pl
- [6] www.xella.pl
- [7] www.termwall.eu
- [8] www.iqdom.pl

