



Internal insulation of historic buildings with earth building materials

Christof ZIEGERT, Eike ROSWAG-KLINGE

Article disponible dans les actes du colloque Terra 2016:

JOFFROY, Thierry, GUILLAUD, Hubert, SADOZAÏ, Chamsia (dir.) 2018, *Terra Lyon 2016: Articles sélectionnés pour publication en ligne / articles selected for on-line publication / artículos seleccionados para publicación en línea*. Villefontaine : CRAterre. ISBN 979-10-96446-12-4.

Summary

Due to ornamented facades of historic buildings, external insulations are often problematic in their feasibility. On the other hand, internal insulations can be very challenging by means of building physics. Constructions with damp-proof layers are prone to leaking and to subsequent moisture ingress from outside (moisture-trap). In the last few years, a significant number of vapour-open capillary-active systems entered the market and got more and more established. Earth building materials are most suitable and highly appropriate for this field of application.

There are two different systems for internal insulation based on earth building materials:

- Inner shell of light earth material as wet application or as light weight block masonry
- Insulation board (wood fibre or calcium silicate foam) bonded and plastered with earth mortar.

For the application of internal insulation, different requirements have to be fulfilled. For example, the plinth of the existing wall must be free of rising damp or other sources of moisture as well as the salt content has to comply with the requirements set out by the WTA (Scientific technical workgroup for the refurbishment of historic buildings and cultural heritage preservation). Construction details like window reveals or bearings of timber ceiling beams have to be designed in detail.

Introduction

The energy consumption of historical buildings has to face reduction nowadays, especially in the northern European climate zones. It must be examined to accurately stage to what extent the subsequent insulation of exterior wall components is suitable for the necessary energy savings. Or if already a sufficient reduction can be achieved through the insulation of the top floor ceiling and the roof, the insulation of the lower floor and the basement ceiling as well as a modernization of the heating system. Depending on the geometry of the building, the building envelope is causing only 30 - 40 % of the energy consumption, whereas about one third of it is determined by windows and not by walls. The insulation of a facade is about twice as expensive as the insulation of the roof and basement ceiling. If the insulation of exterior wall components continue to appear useful or even necessary for the project - even after these critical considerations - it is the type of insulation that needs to be considered carefully for each specific case. Since the external insulation of historic facades is often not possible due to design and / or historic preservation reasons, it is only the internal insulation with its building physics challenges that remains for insulating the exterior wall components. Earth building materials with their specific physical properties are ideally suited for this complex internal insulation.

1 external insulation vs. internal insulation

Both the exterior and the interior insulation have advantages and disadvantages, which must be individually weighed for each object. Some factors that may facilitate this decision are listed below for both the exterior insulation as well as for internal insulation by + (pros) and - (cons):

External insulation

- + structural-physical unproblematic with respect to condensation in the construction
- + with the same insulation thickness: insulation effect is better than internal insulation
- often problematic in the field of visual appearance and design

- surface condensation and formation of algae cannot be excluded
- scaffolding costs
- adjustment of roof drainage, window sills etc.
- exceeding of the property boundaries

Internal insulation

- + apartments can be insulated independently
- + no scaffolding costs
- + light earth in plastic mounting: thickness compensation without additional layers
- + rapid heating of the room
- building physics analysis is necessary due to heavy losses in case of miscalculated setup
- tolerance to driving rain decreases
- reduced insulation effect due to embedded components (e.g. ceilings or cross walls)
- loss of (living) space
- installations and details need to be adapted
- partial loss of thermal inertia (negative for summer heat protection)

The question of external insulation does not arise when it comes to decorated and/or historic facades. In this case, it is only an internal thermo-technical improvement that can be applied to exterior walls.



Fig. 1: The external insulation of historic buildings would often mean a loss of cultural identity

Germany's regulatory technical framework is constituted as follows: according to the Energy Saving Ordinance 2014 (EnEV), there is no general obligation for subsequent insulation of external walls of existing buildings. The external wall must only be insulated if outside work on the component is taking place, like completely replacing the wall, lagging the wall or if the external plaster gets modernized.

For interior insulation, minimum values for the U-value were set up by EnEV. However, it is the highest possible insulation thickness - in accordance with the recognized rules of technology - that needs to be installed. The potential damage of too thick internal insulations is hereby taken into account by EnEV. Thus, a „reasonable“ insulation measure is accredited, according to the state of the art. However, the minimum heat insulation protection in accordance with DIN 4108-2 with a thermal resistance of $> 1,2 \text{ m}^2 \text{ K} / \text{W}$ (equivalent U-value $< 0.83 \text{ W} / \text{m}^2 \text{ K}$) is to be observed in any case.

2 light earth internal insulation vs. insulation panels embedded in earthen mortar

In general, there is a distinction to be made between internal insulation of thermally insulating earth building materials ($\lambda = 0.1 \dots 0.2 \text{ W} / \text{mK}$) and internal insulation of capillary-insulating materials ($\lambda < 0.1 \text{ W} / \text{mK}$) with adhesive earthen layers and earthen plaster layers. Both techniques are used in the renovation of half-timbered walls as well as for solid earth buildings, brick and natural stone buildings [1].

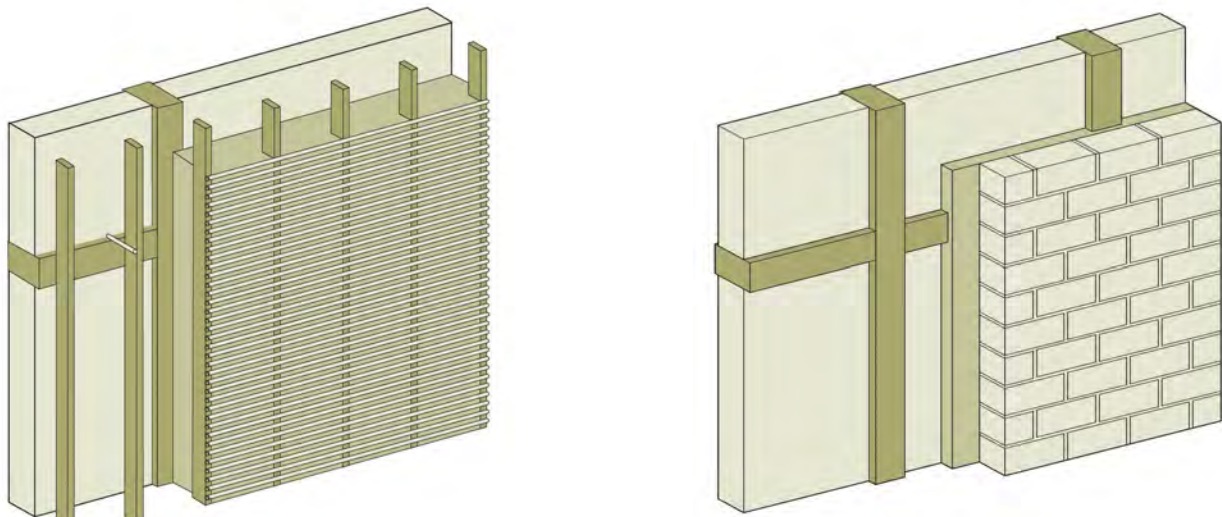


Fig. 2 a and b light earth as final lining: ductile embedded (a) or masoned (b)

The experience with internal insulation with light earth application is an established practice since the last three decades. In contrast to the embedded version of insulation panels in earthen mortar, this is in practice only since the last ten years. The functioning of both types of interior insulation is based on the principle of capillary action, i.e. possibly condensate is transported by capillary active earth building materials (and insulation). Thus, these systems are also moisture-tolerant in case of driving rain or structural damage. In this type of component layering, the moisture can not get enclosed by vapour trap or steam brakes. Moisture, which arises through the building materials, can become critical with light earth internal insulation systems during the construction phase. Here, intensive drying efforts are required. Furthermore, in order not to produce too much condensation, an overdimensioning of the internal insulation should be avoided. A meaningful, mathematically demonstrable and proven practice is an insulation thickness of 6 to 8 cm. Soft wood fiber insulation boards and mineral foam panels can be recommended as established materials for internal insulation.



Fig. 3a and b interior insulation with soft fibreboards (a) and mineral foam pannels (b) embedded in earthen mortar

The initially used reed pannels show no calculative evidence, already from a thickness of 4 cm. Therefore, this kind of application already decreases. Wood fiber pannels are flexible and therefore rather used for internal insulation of timber-framed buildings. For solid constructions, the use of mineral foam boards predominates.

Light earth internal insulation has the following + (pros) and - (cons), compared to internal insulation with insulating materials:

- + physical unproblematic if not too light weighed
- + high thermal storage capacity at moderate heat insulation
- + thickness compensation without additional layers when embedded in light earth mortar
- loss of (living) space due to thick layers
- high loads: interception is necessary for multi-storey buildings
- long drying time due to levelling courses for light earth final lining and when embedded.

Especially the last point was creating a lot of damages in the last time (Fig. 4) and was not proper discussed in the literature that focused on the light earth internal insulation [2], [3].



Fig. 4a and b Mould and fungi development because of a too slowly drying processof the light earth interior insulation, Germany

Interior insulation with thermal insulation, adhesive earthen layers and plaster layers have therefore the following (+) advantages and (-) disadvantages compared to light earth insulation:

- low thermal storage capacity
- a careful building physical examination is necessary
- + low heat loss
- + light loads
- + short drying times when no compensation layers necessary
- + low heating-up times of rooms

Historic half-timbered and solid structures are largely unproblematic in terms of thermal bridges with embedded components (e.g. embedded cross walls in the exterior wall). However, the building physics analysis of the ceiling joist support can be regarded as imperative, at least in historic brick buildings.

The building physical properties of earthen interior insulation materials can be determined using specialised computer software that takes into account the capillary transmission properties of existing and insulation materials e.g. COND, WUFI or DELPHIN. The last two programs also consider the driving rain exposure at specific geographical locations. Such analyses show that the moisture from rain exposure can drastically increase the resulting level of condensation.

3 Best practice

3.1 Lime stone-Pisé-barn in Ribbeck near Berlin

This former sheepfold was built mid-19th century in lime-pisé-construction. First, comprehensive measures of crack repair, exsiccation and desalination have been executed. After the completion of these measures, a 15 cm thick interior insulation layer of light earth with hemp could be installed. The U-Value of the wall is reduced with the insulation from 1.2 down to 0.59 W/m²K.



Fig. 5a and b light earth interior insulation with hemp. Former sheepfold Ribbeck / Germany

3.2 Granary in Freiberg

This historic granary with 3 full storeys and 3 attic storeys was converted into a library. The historic stone walls are made of very heavy and thus highly thermally conductive gneiss. Before applying the internal insulation system, the walls were drained to the foundation. The walls were desalted with a temporary earthen plaster that detracts the salt out of the walls, the so-called „Opferputz“ or oblation plaster. The physical analysis showed that the natural stone walls are so strong diffusion braking that only an internal insulation with mineral foam boards could be implemented. The pannels are embedded and plastered with clay. The U-Value of the wall is reduced with the insulation of 6 cm mineral foam board from 1.3 down to approximately 0.50 W/m²K.



Fig. 6a and b internal insulation of mineral foam pannels (embedded and plastered with clay) and wall heating system at a granary in Freiberg / Saxony in Germany

Conclusion

For design and historic preservation reasons, the installation of an external insulation is often not possible for historic buildings. Thus, only an internal insulation can be considered if the outer walls still need to be insulated. Interior insulation with earthen building materials are applied with a strong upward trend both in the renovation of half-timbered buildings with earthen infill and solid constructions as well as for brick and natural stone buildings. Due to the capillary activity of the systems, these types of internal insulation can be installed without braking or blocking films. Furthermore, these earthen interior insulation systems are fault-tolerant systems. The thermal transmittance of historic wall structures can thus be substantially reduced, but not lowered to new building levels.

Bibliographical references

- [1] English Version: Röhlen, U., Ziegert, C. (2011). *Earth Building Practice*, Beuth-Verlag, Edition Bauwerk, Berlin, ISBN 978-3-410-21737-4
French Version: Röhlen, U., Ziegert, C. (2013). *Construire en terre crue*, Edition Le Moniteur, Paris, EAN13: 9782281115673
German Version: Röhlen, U., Ziegert, C. (2014). *Lehmbau Praxis*, Beuth Verlag, Edition Bauwerk, Berlin, ISBN 978-3-410-23942-0, 2. completely revised Edition (04/2014)
- [2] Volhard, Franz (2016). *Light Earth Building. A Handbook for Building with Wood and Earth. 8th revised and expanded edition*, Birkhäuser Verlag, Basel 2016
- [3] Minke, Gernot (2009). *Handbuch Lehmbau – Baustoffkunde, Techniken, Lehmarhitektur*. Ökobuchverlag. Staufen