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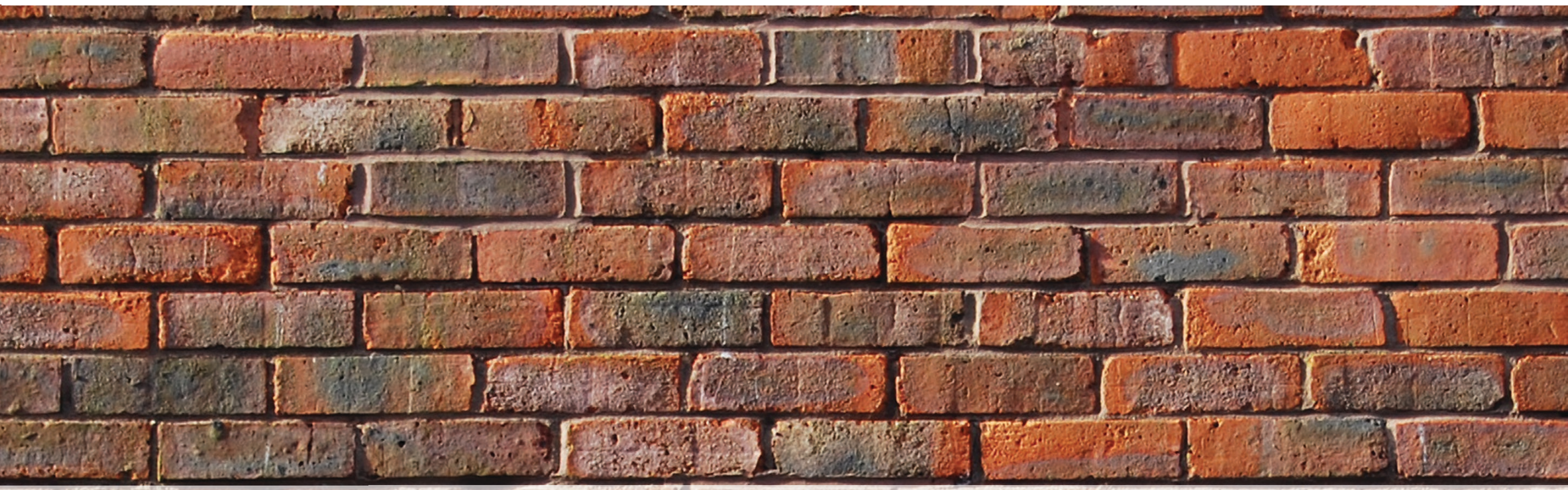
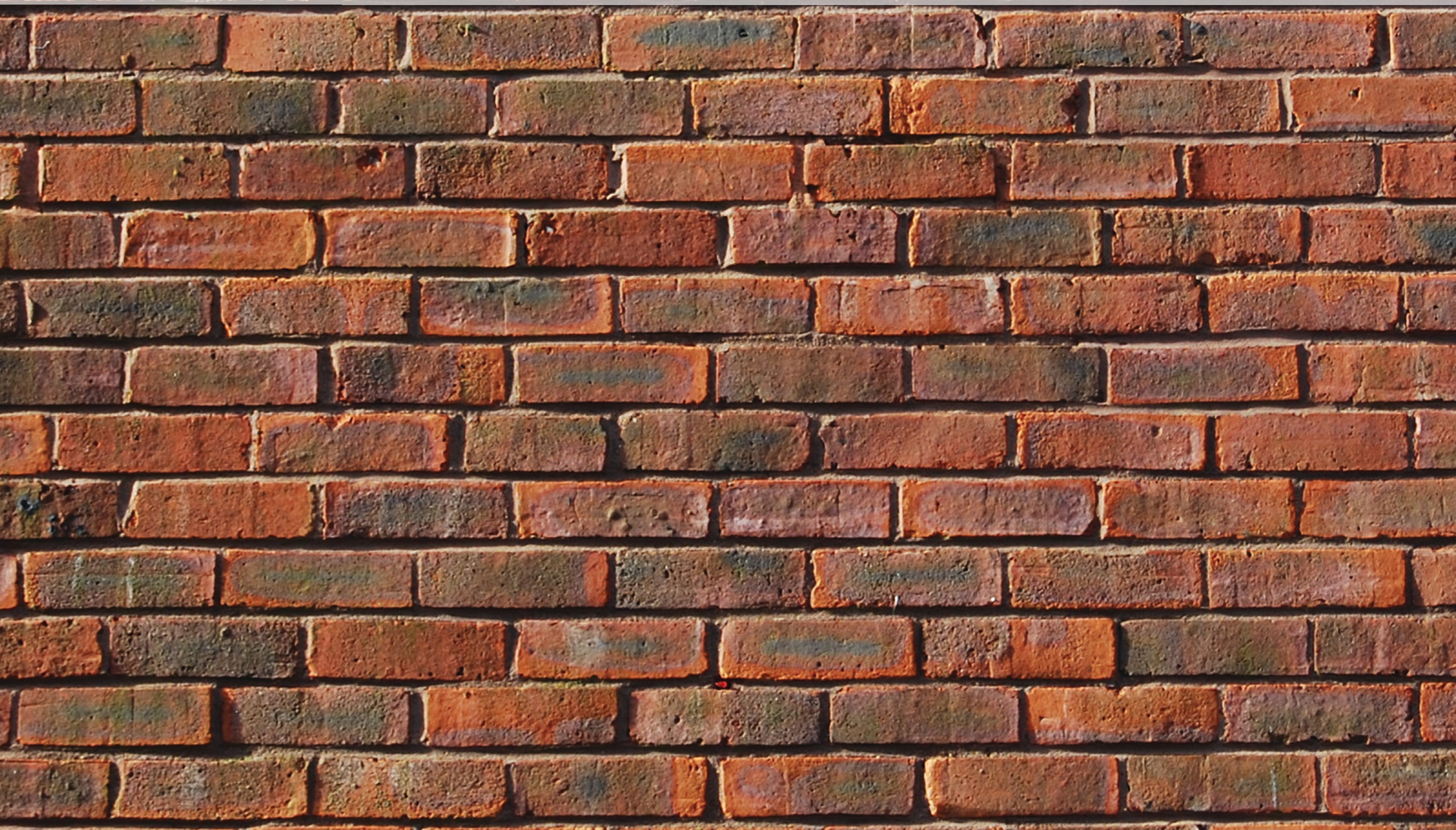


WP5 Education and Economic Promotion

Post-insulation of outer walls

Educational product: New lecture material for training modules dealing with knowledge and skills how to apply suitable methods of energy efficient refurbishment of historic constructions and how innovation can be combined with cultural heritage



Post-insulation of outer walls

Target group: architecture, construction, energy audit students

Educational objectives: To give the systematic knowledge of typical brick wall construction in BSR, possible problems from inside insulation and ways to avoid it.
This measure can help to save up to 14% total energy used in building

Lecture course: 4 academic hours, additional on-site visit recommended

References:

Ueno, K., and R. Van Straaten. *Expert Meeting Report: Interior Insulation Retrofit of Mass Masonry Wall Assemblies*. US Department of Energy, Energy Efficiency & Renewable Energy, 2012.

Rasmussen, Torben Valdbjørn. "Post-insulation of existing buildings constructed between 1850 and 1920." *Department of Construction and Health, Danish Building Research Institute, Aalborg University, Hørsholm* (2010).

Byrne, Aimee, et al. "Transient and quasi-steady thermal behaviour of a building envelope due to retrofitted cavity wall and ceiling insulation." *Energy and Buildings* (2013).

Roberts, S., and R. Stephenson. "Measure Guideline: Wall Air Sealing and Insulation Methods in Existing Homes." (2012).

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Introduction

The project "CO_2ol Bricks" considers measures to improve the thermal envelope of buildings constructed with exterior walls of Brick. Measures with a focus on good technical solutions for improving the thermal insulation of the building envelope are outlined. Both buildings with a recognised unique architecture, where measures must be carried out at the inside, and buildings without a recognised unique architecture, where measures can be carried out at the indside as well as the outside, are shown.

However, special attention should be paid to prevent degradation of the existing construction when the energy demand for heating and thermal comfort of a building decreases as a result of measures to improve the thermal envelope. Besides lower heating costs and reduced CO_2 emissions, improvement of the insulation standard could contribute to the elimination of other aspects of discomfort e.g. from draught originating from cold surfaces inside. Building physics requirements of importance is addressed as well.

Houses built before 1980 often have little or no wall insulation. Given that walls can represent most of the building envelope area, ensuring that walls have proper levels of insulation is an essential part of any historic building energy retrofit. Post-insulation of outer walls is the most challenging and most energy effective measure for historic building. The retrofit of interior insulation is commonly implemented to improve energy performance of these buildings, while maintaining their often historic exterior appearance.

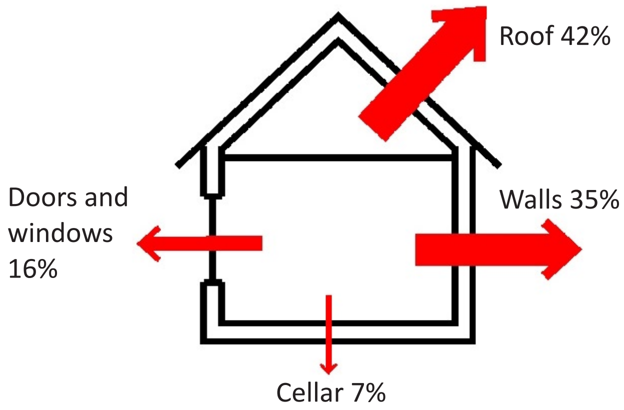

Fig. 1. Energy losses in typical historic building in BSR

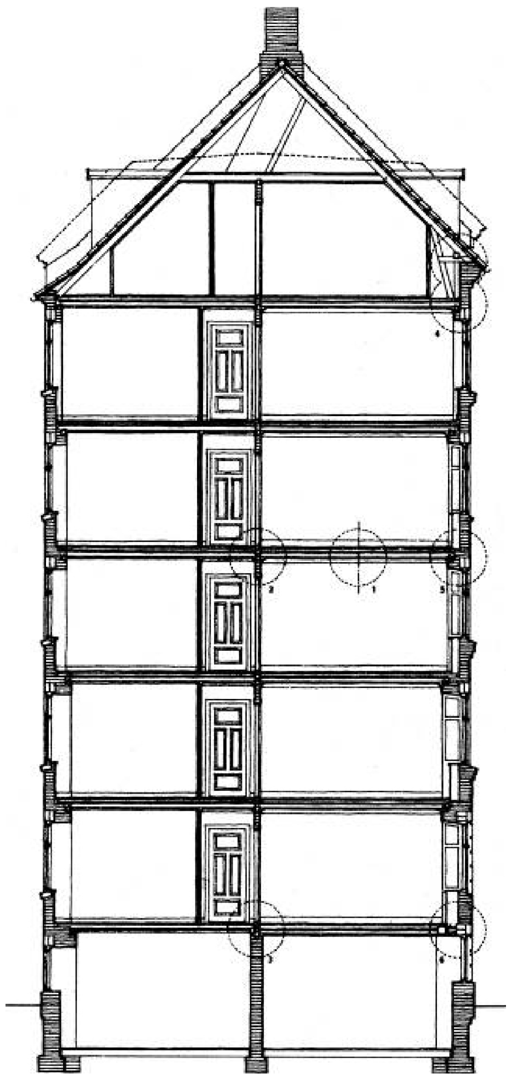

Fig. 2. Typical historic multi-storey building in BSR constructed with a thermal envelope of brick. Before 1920 the horizontal partition was constructed by timber beams. Later horizontal partitions of concrete were introduced.

Insulation is a key tool in the fight to save energy used in buildings. However, in the rush to insulate consideration must be given to the types of materials used and how suited they are to the original construction. Inappropriate use of cheap, impermeable materials can cause an imbalance in the movement of air and moisture in a building and could lead to problems of decay and damage which in the long run will cost more to remediate.

Buildings with an exterior wall of solid brick were until 1920 constructed with horizontal partitions of timber beams, see Figure 1 and Figure 2. Later horizontal partitions of concrete were introduced. The typical brickwork of the exterior wall, of buildings constructed before 1920 and especially between 1850 and 1920, is three bricks in thickness at the base of the building decreasing to one and a half brick at the top level, see Figure 3. The two top stories have a cavity wall with solid wall ties. Where the loadbearing exterior wall supports the timber beams, the solid brick wall decreases in thickness by half a brick every two storeys. The timber beams reach into the brick wall, see Figure 3, and at the top level of the building, the protecting shield reaches half a brick. The window wall under the windows is one brick in thickness, see Figure 4. The window is attached to the exterior wall, see Figure 5 and Figure 6. The non-loadbearing house ends have a thickness of one and a half bricks, see Figure 7.

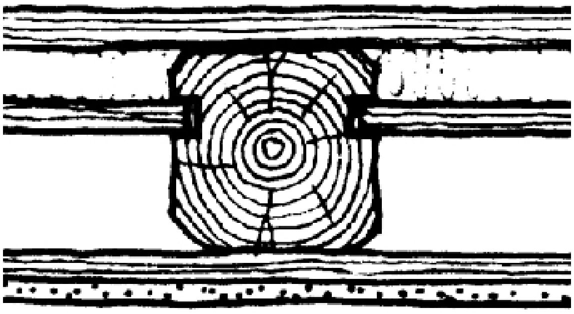

Figure 3. Horizontal partition by timber beams. From the top: floor board, clay infill, wooden boards, empty space, wooden boards and a layer of plaster on straw. The timber beams are of a good quality with the dimensions 200 mm by 200 mm with a tolerance from top to bottom of 6.25 mm.

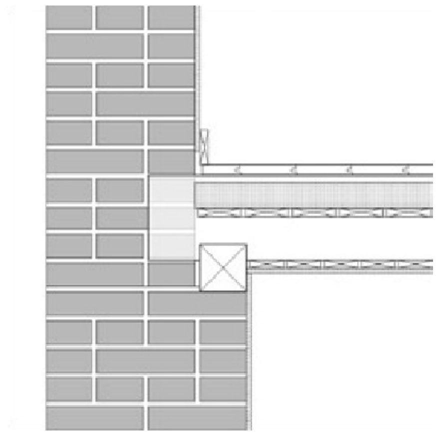

Figure 4. Vertical section of the joint between the exterior loadbearing wall, which is the facade, and the horizontal partition. The exterior wall is a solid brick wall that decreases in thickness by half a brick every two storeys. The timber beams reach into the brick wall.

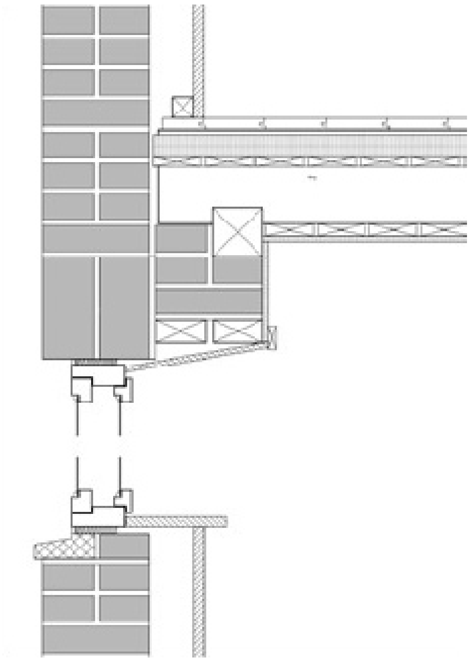

Figure 5. Vertical section of the joint between the loadbearing exterior wall and the horizontal partition at the window wall.

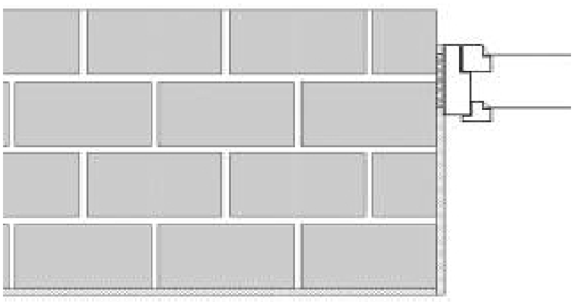

Figure 6. Horizontal section of the joint between the loadbearing exterior wall and the window.

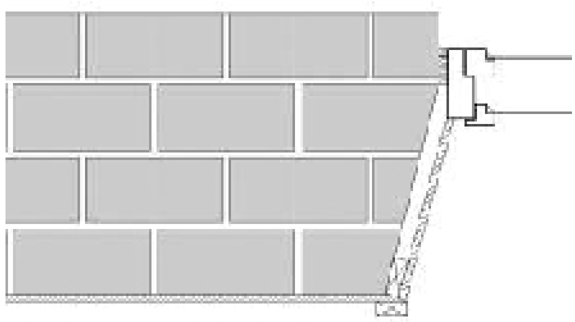

Figure 7. Horizontal section of the joint between the loadbearing exterior wall and the window.

Measurements to improve the thermal insulation of the building envelope

Buildings with a recognised unique architecture

Although outside insulation is the most efficient way to improve the insulation standard of an building, it might not always be an option for buildings with a recognised unique architecture. Therefore resonable measures to be carried out at the inside of the exterior wall must be considered. When designing the solution for the measure to improve the thermal envelope, special attention must be paid to prevent the risk of condensation in the exterior wall due to air leakage and moisture, penetrating into the building envelope from the inside as well as from the outside.

It must be realised that for the measures to improve the thermal envelope it might not be possible to eliminate thermal bridges. However, in some cases thermal bridges can be used to maintain the temperature at critical locations in the building envelope at a high temperature level and thereby decrease the moisture level.

Figure 8 and Figure 9 show the measure system used, which consist of a timber stud frame with 95 mm mineral fibre insulation. A stainsless steel frame cam also be used. The timber stud frame is attached to the horizontal partition between the individual floors of the building and kept clear of the exterior wall of the building envelope. The cavity between the timber stud frame and the exterior wall is filled with mineral fibre insulation. To prevent air and moisture from penetrating into the insulated exterior wall from the inside, an airtight shell is established. The airtight shell is established by a 0.2 mm polyethylene foil that also serves as the vapour barrier. It is crucial that the foil is located at the warm side of the dew point and that the joints between the sheets of foil and joints are airtight and securely fixed. For the timber stud frame wall, for the loadbearing facade, the foil is brought to the exterior brick wall and fixed airtight by a lath. For the non-loadbearing wall at the house end, the foil is brought to the timber beam of the horizontal partition and fixed airtight. Measures at the free house end can be carried out on the outside without changing the architecture of the building. Figure 13 shows the improved thermal insulation system that can be used for the non-loadbearing wall at the house end, which consisted of 195 mm mineral fibre insulation covered by a layer of plaster at the exterior side.

Contributing to a flagship project of the strategy
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Co2olBricks

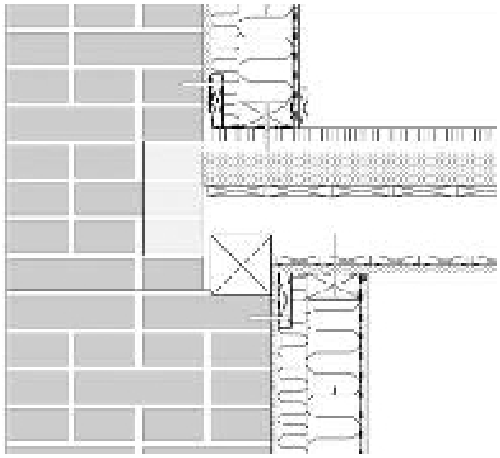

Figure 8. Vertical section of the joint between the loadbearing wall, which is the facade, and the horizontal partition after improved thermal insulation measures.

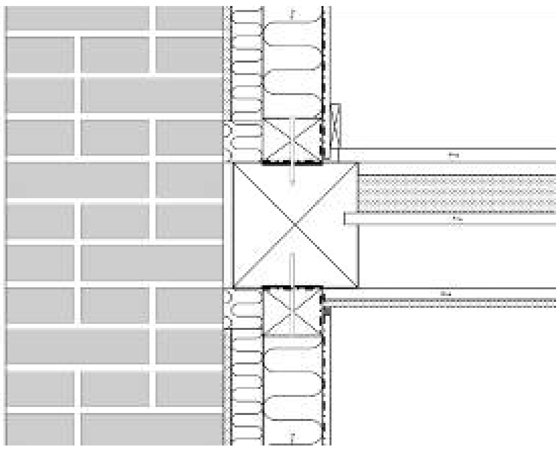

Figure 9. Vertical section of the joint between the horizontal partition and the non-loadbearing house end after improved thermal insulation measures.

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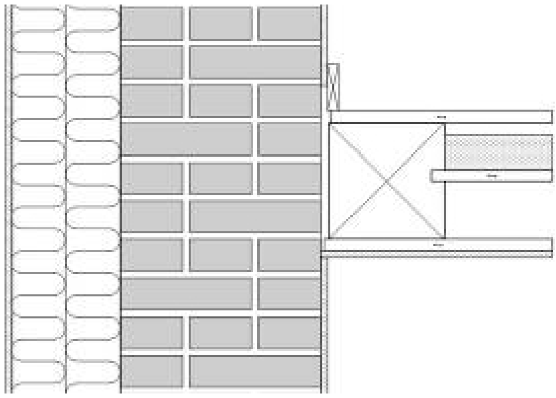

Figure 10. Vertical section of the joint between the horizontal partition and the free non-loadbearing house end after improved thermal insulation measures. The structure of the horizontal partition is shown in Figure 2.

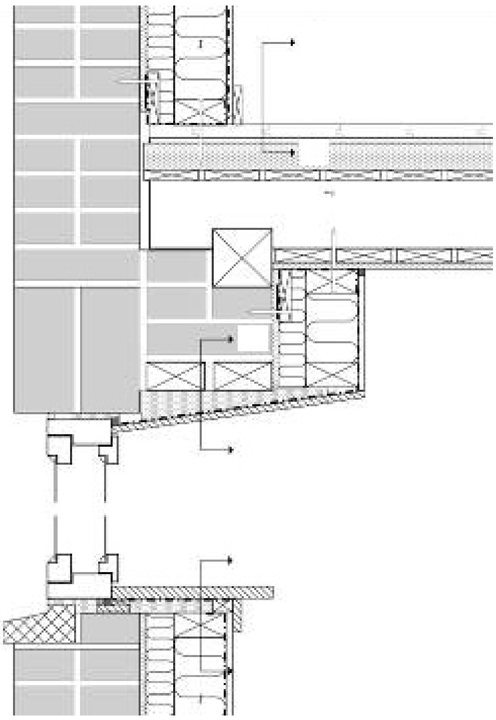

Figure 11. Vertical section of the joint between the loadbearing exterior wall and the horizontal partition at the window wall after improved thermal insulation measures.

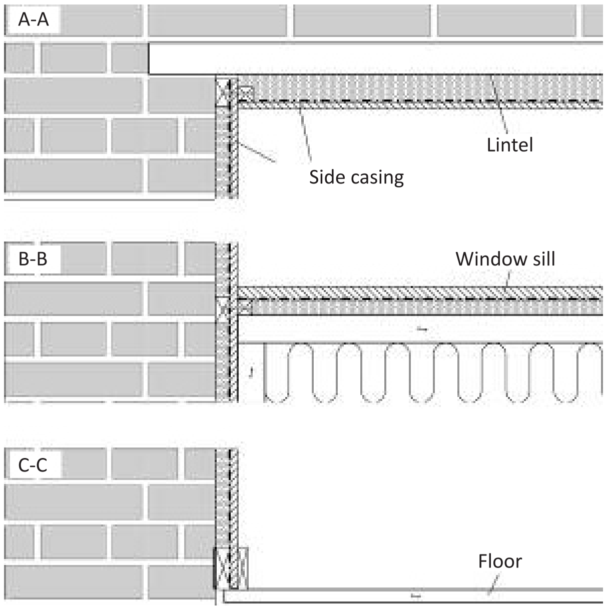

Figure 12. Sectional view of sections A-A, B-B and C-C, see Figure 16.

Figure 13 shows improved thermal insulation measures where the insulation is brought to the existing window by insulation located behind the narrow sill. The insulation located behind the narrow sill is placed there to minimise the thermal loss in the joint between the window and the exterior wall. Figure 17 shows sectional views from Figure 13. Figure 15, Figure 16 and Figure 17 show improved thermal insulation measures where the insulation is brought to the existing window and the window wall, see Figure 17.

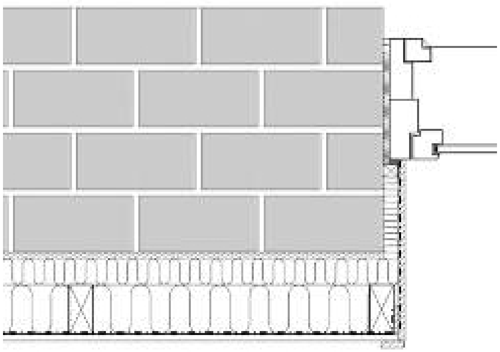

Figure 13. Horizontal section of the joint between the loadbearing exterior wall and the window after improved thermal insulation measures.

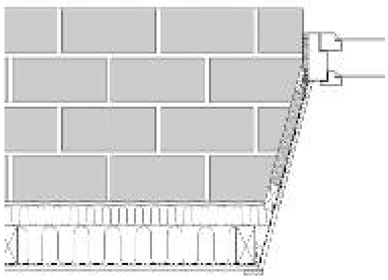

Figure 14. Horizontal section of the joint between the loadbearing exterior wall and the window after improved thermal insulation measures.

Buildings without a recognised unique architecture

Buildings with an exterior wall of solid brick were in a period of time after 1920 constructed with horizontal partitions of concrete. Until 1960 exterior walls of solid brick was used although cavity walls became more rear. Measures increasing the thermal insulation of the thermal envelope of these buildings are presented below.

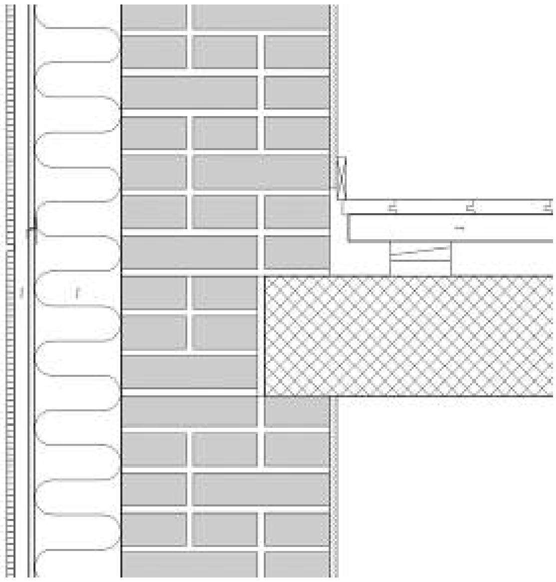

Figure 15. Vertical section of the joint between the horizontal partition and the loadbearing exterior wall after improved thermal insulation measures.

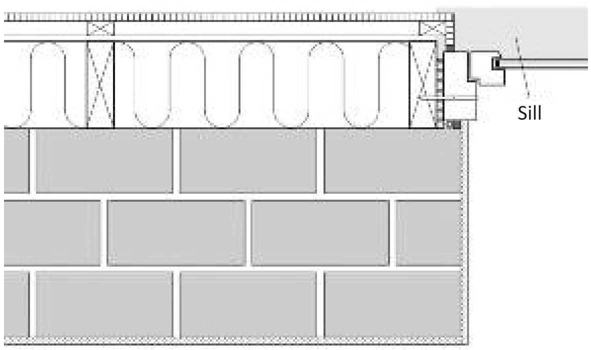

Figure 16. Horizontal section of the joint between the loadbearing exterior wall and the window after improved thermal insulation measures. The window has been replaced.

Building physics requirements

When improving the thermal insulation of the building envelope, it is of crucial importance to take advantage of measures that prevent moisture problems and degradation of the existing construction.

Prior to carrying out post-insulation, a critical examination of the building must ensure that the building is suitable for the planned measures. If not suitable, additional work must be carried out to comply with the technical requirements for carrying out the measurements.

Special attention must be paid to ensure that, for the improved thermal building envelope, problems related to temperature decrease and moisture increase are not introduced. Measures to improve the insulation of the building envelope will change the overall condition of the existing construction. The temperature of the exterior brick wall will decrease at the facades by adding an insulation layer to the inside and will put the wall at risk from water damage and spalling. Furthermore, attention must be paid to preventing condensation in the exterior wall due to air leakage and moisture, penetrating into the building envelope from the inside as well as from the outside.

Special attention should be paid to analysing locations like where the timber beam of the horizontal partition reaches into the brick wall. Measures carried out inside to improve the thermal insulation at the thermal envelope at such locations will leave such locations at a colder environment than originally.

Test methods that can be used to evaluate the wall system of the existing building including requirements of the test method, application of the test method and interpretation of test results is required. Historical test data that illustrate the use of the test methods can be used to evaluate wall systems and expected range of test results for existing and repaired wall systems. For the measures for improving the thermal insulation of the thermal envelope, it must be feasible to establish an airtight shell as well as a vapour barrier that comply with the technical requirements for joints as well as for ceiling preventing the construction adequately from indoor moisture exposure.

Internal wall insulation and external wall insulation in historic buildings

When insulating walls from inside it is important to understand how this will affect the existing wall. There is an opinion that walls should not be insulated from inside because temperature level in the existing brick wall will be lowered and this will increase the speed of brick wall deteriation.

When insulating walls in historical buildings from outside it is very important not to alter the appearance of the building. In many cases insulating walls in historical builidngs from outside is not allowed by govermental institutions responsible for cultural heritage.

Insulation material changes temperature distribution in walls. In Figure 17 temperature distribution in brick walls is shown in case of internal and external wall insulation.

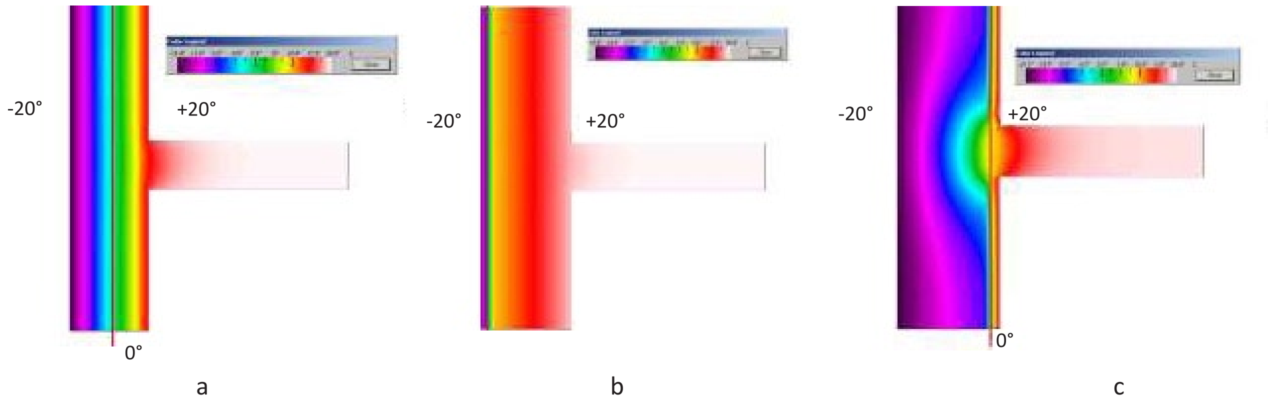

Fig. 17. Temperature distribution in brick wall for uninsulated wall (a), wall with external insulation (b) and wall with internal insulation (c)

As can be seen in the figure 17 biggest temperature drop happens in the insulation material because of its low heat conductivity. In case if indoor air temperature is +20 $_{o}$C and outdoor air temperature is -20 $_{o}$C the temperature on the surface between brick wall and insulation material for external insulation is +9 $_{o}$C but for internal insulation it is -10 $_{o}$C. This means that in case of external insulation brick wall in all weather conditions does not reach temperatures lower than 0 $_{o}$C – there is no chance of water vapor or liquid water that is in the brick wall to freeze and damaging the existing brick wall. In case of internal insulation temperature in brick wall can easily drop under 0 $_{o}$C, which means that wator vapor or liquid water that is in the brick wall can freeze and create damage to this wall. Therefore it is very important for walls that have internal insulation also to have vapor barrier that does not allow vapor transport in the wall. Also it is very important that wall that has to be insulated from inside is dry and does not contain too much water in any state. If the wall is wet it should be dried before insulating the wall from inside.

If wall is insulated from inside then the usual solution is a wooden carcass, which is filled with insulation material and afterwards covered with gypsum boards or other finishing materials. If wall is insulated from outside then for historical brick buildings there is a solution where the insulation board imitates brick masonry.

External insulation

Internal insulation

Fig. 18. Insulation material for external insulation has to imitate bricks if it is while internal insulation has no such needs [http://www.sustainablebuildingsolutions.co.uk/training_courses/thermoshell-internal-wallinsulation-installer]

If the same material thickness is used in both internal or external wall insulation, the Uvalue (heat transfer coefficient) will be the same. Only if wall has internal insulation then larger thermal bridges will be observed in the places where ceiling meets wall.

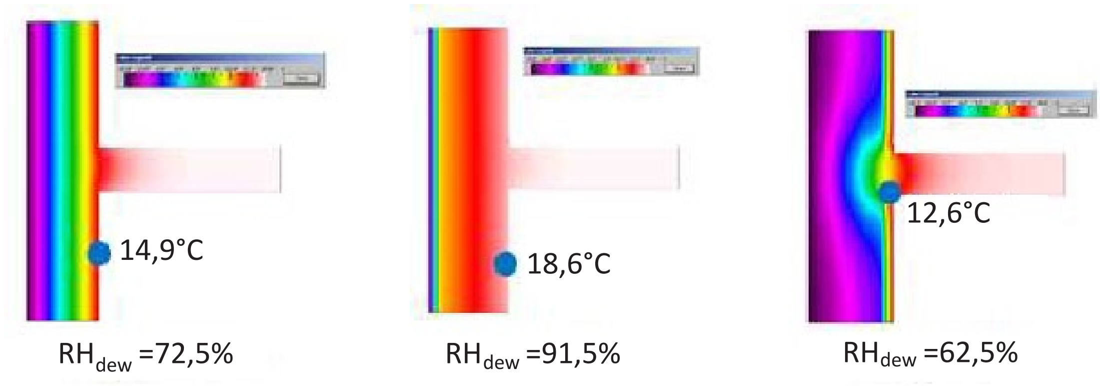

Fig. 19. Minimal temperatures and relative indoor air humidity at which condensation will form

As can be seen from Figure 19 the lowest temperature on wall surface will be observed for the case when wall is insulated from inside. In this case surface temperature at the point where wall meets ceiling will be 12,6 $_{o}$C, while minimal surface temperature on uninsulated wall will be 14,9 $_{o}$C, but for insulated wall it is 18,6 $_{o}$C. If indoor air relative humidity will be higher than 62,5% condensation will form on surface of wall that is insulated from inside. In the same time for wall that is insulated from outside relative air humidity has to be higher than 91,5% for condensation to form on inner wall surface.