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MEASURES TO IMPROVE THE THERMAL ENVELOPE OF SOLID BRICK BUILDINGS

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Background

Tightened requirements to thermal insulation of new buildings and the resulting demand for a reduction of energy consumption for heating and comfort in order to reduce CO_2 emissions mean that existing and especially older buildings have a very low thermal standard compared with today's requirements. Therefore, there is an increased interest in improving the insulation standard of many existing and older buildings.

The project CO2Ol 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.

Existing buildings with a thermal envelope of brick

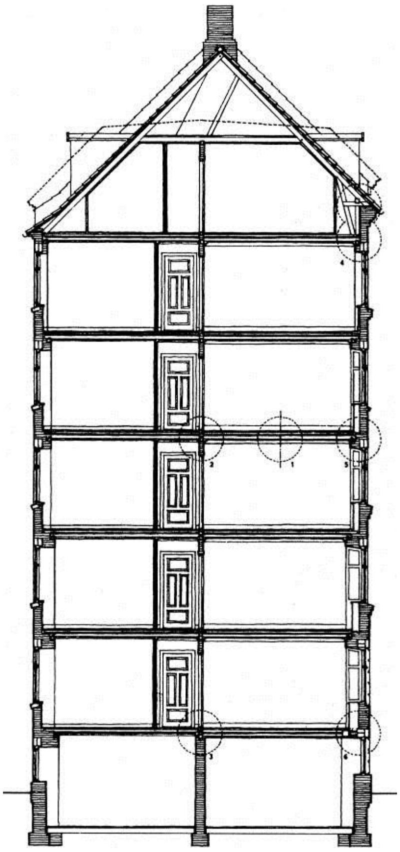

Figure 1. multi-storey building with flats constructed with a thermal envelope of brick. Before 1920 the horizontal partition was constructed by timber beams. Later horizontal partitions of concrete were introduced.

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.

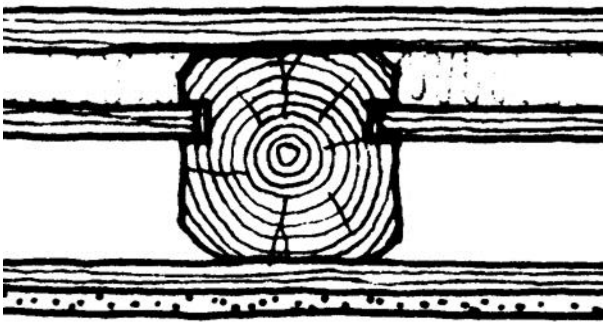

Figure 2. Horizontal partition by timber beams. From the top: floor board, clay infill, wooden boards, empty space, wooden boards and a layer of plaster on straw. The timber beams are of a good quality with the dimensions 200 mm by 200 mm with a tolerance from top to bottom of 6.25 mm.

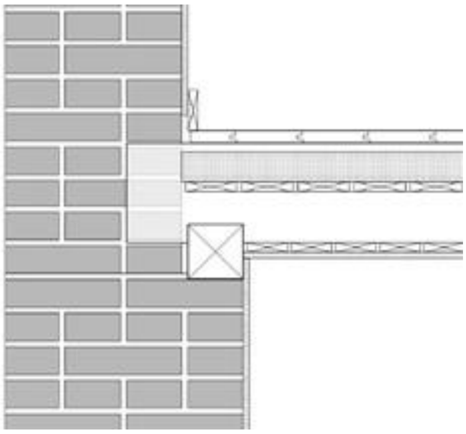

Figure 3. Vertical section of the joint between the exterior loadbearing wall, which is the facade, and the horizontal partition. The exterior wall is a solid brick wall that decreases in thickness by half a brick every two storeys. The timber beams reach into the brick wall.

The building has a basement and a cold attic room. The roof is typical a double-pitched roof with a 45 degree angle. The vertical section of the junction between the bases of the roof at the loadbearing exterior wall at the facade is shown in Figure 8. The joint of the roof base at the non-loadbearing house end is similar to the joint of the horizontal partition at the non-loadbearing house end, see Figure 7.

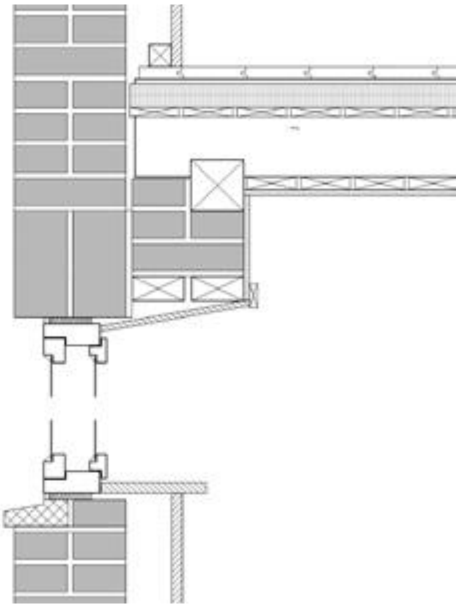

Figure 4. Vertical section of the joint between the loadbearing exterior wall and the horizontal partition at the window wall.

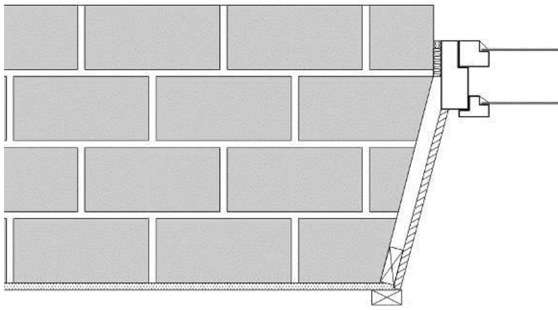

Figure 5. Horizontal section of the joint between the loadbearing exterior wall and the window.

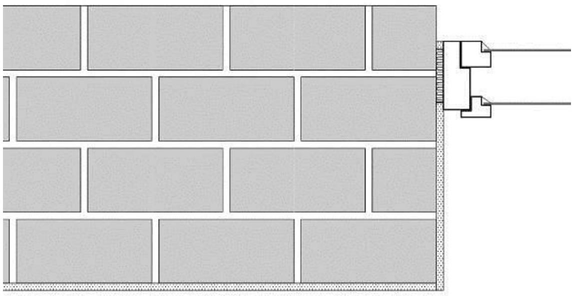

Figure 6. Horizontal section of the joint between the loadbearing exterior wall and the window.

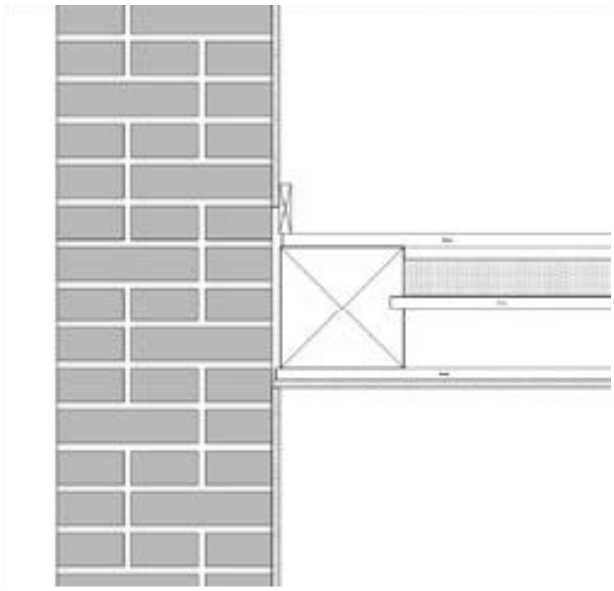

Figure 7. Vertical section of the joint between the horizontal partition and the non-loadbearing house end.

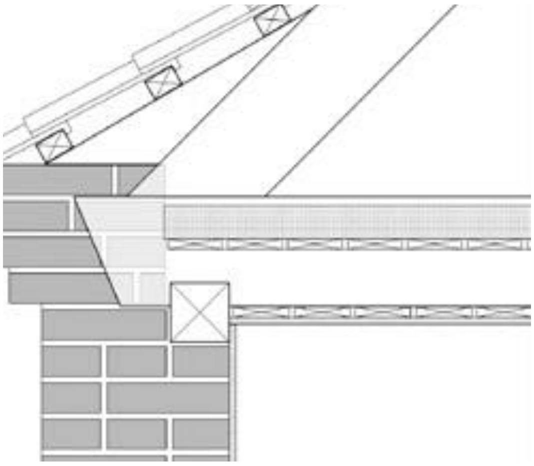

Figure 8. Vertical section of the joint between the base of the roof and the loadbearing exterior wall.

The basement was originally used for storage e.g. coal for heating. The exterior wall of the basement is three bricks in thickness. However, under the windows the wall is one and a half bricks, see Figure 9. The horizontal partition to the basement is constructed in the same way as shown in Figure 2. The basement floor is of stamped clay covered with concrete. The basement wall is founded on a foundation of brick, four bricks in thickness based on earth fill that includes stones and bricks, see Figure 10.

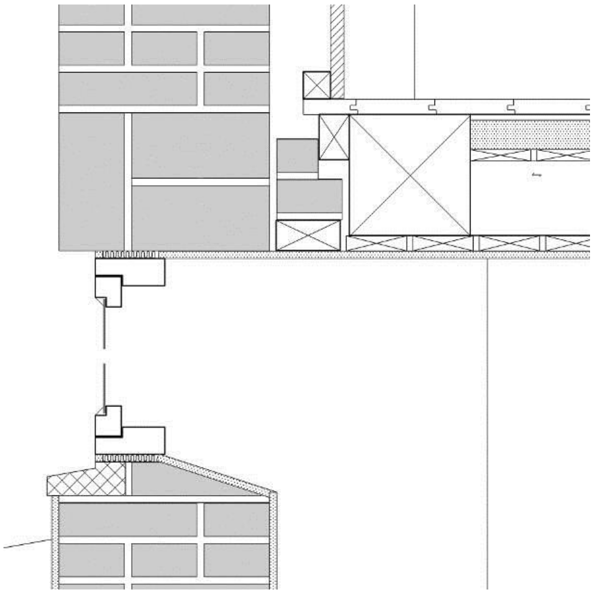

Figure 9. Vertical section of the joint between the loadbearing exterior wall and the horizontal partition at the window wall in the basement.

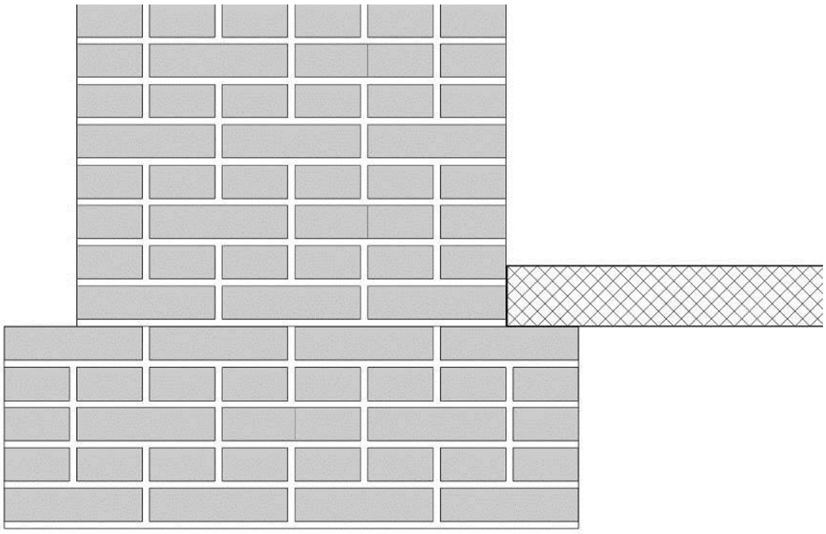

Figure 10. Vertical section at the base of the loadbearing exterior wall in the basement.

Measurements to improve the thermal insulation of the building envelope

A) 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 11 and Figure 12 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.

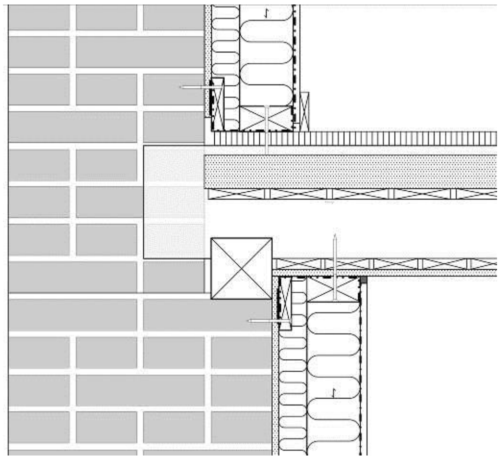

Figure 11. Vertical section of the joint between the loadbearing wall, which is the facade, and the horizontal partition after improved thermal insulation measures.

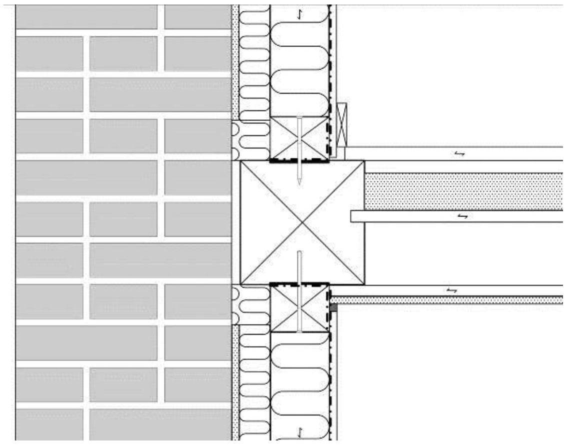

Figure 12. Vertical section of the joint between the horizontal partition and the non-loadbearing house end after improved thermal insulation measures.

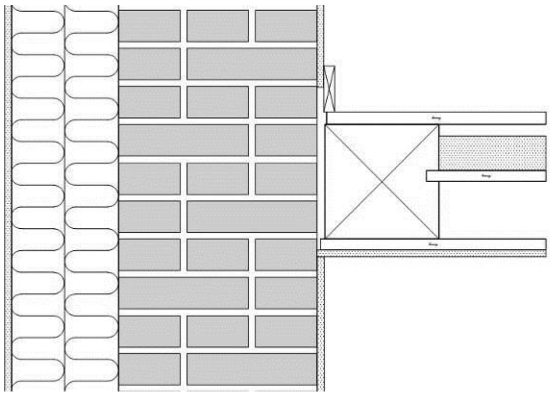

Figure 13. Vertical section of the joint between the horizontal partition and the free non-loadbearing house end after improved thermal insulation measures. The structure of the horizontal partition is shown in Figure 2.

The plaster of the ceiling towards the cold attic room must be intact without cracks. Improvements of the vertical section is carried out by blowing loose-fill mineral fibre insulation into the cavity between the timber beams, see Figure 14. The cavity allowed 100 mm mineral fibre insulation. For further improvements of the thermal insulation towards the cold attic room a polyethylene foil that also serves as the vapour barrier is placed at the attic floor and brought to the timber beam of the horizontal partition and fixed airtight. Mineral fibre insulation is placed above the polyethylene foil, see Figure 15.

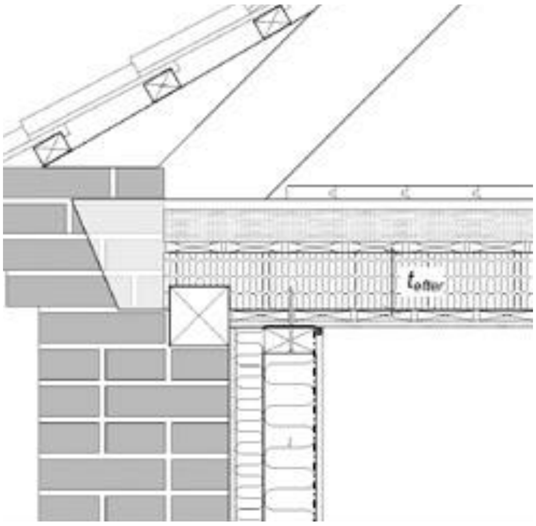

Figure 14. Vertical section of the joint between the base of the roof at the loadbearing exterior wall. The improved thermal insulation measure is carried out by blowing loose-fill mineral fibre insulation material into the cavity between the timber beams underneath the clay infill.

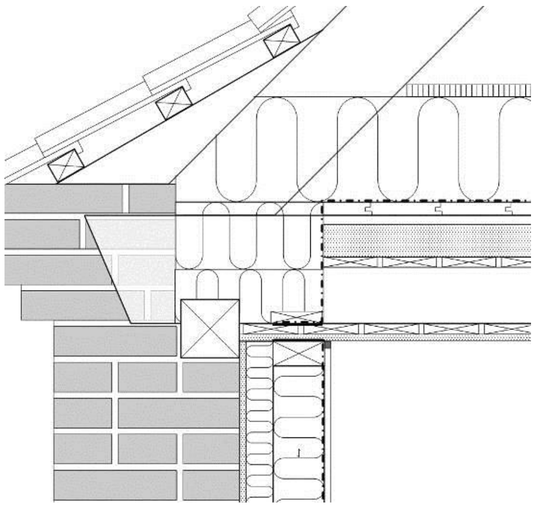

Figure 15. Vertical section of the joint between the base of the roof at the loadbearing exterior wall. Mineral fibre insulation is placed on the floor boards above the polyethylene foil.

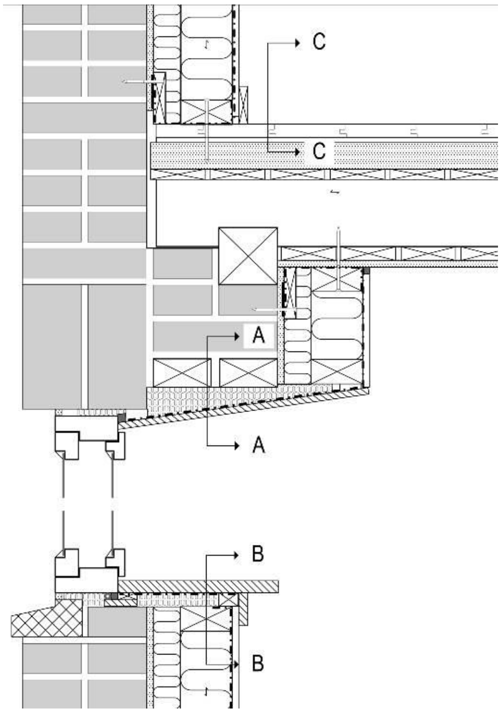

Figure 16. Vertical section of the joint between the loadbearing exterior wall and the horizontal partition at the window wall after improved thermal insulation measures.

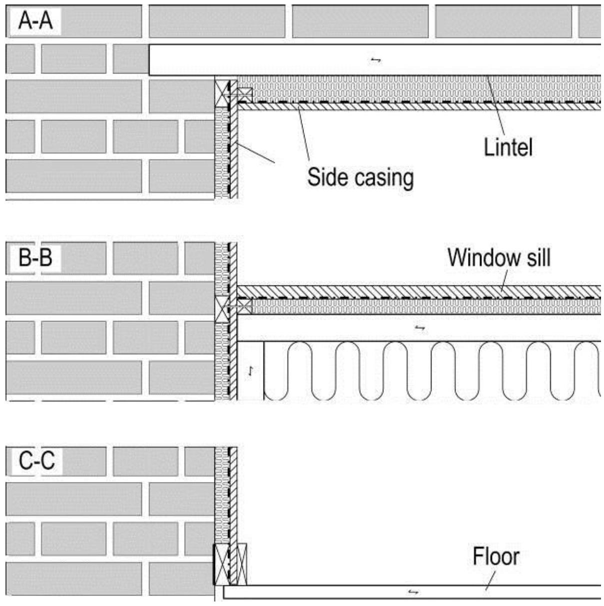

Figure 17. Sectional view of sections A-A, B-B and C-C, see Figure 16.

Figure 16 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 16. Figure 18, Figure 19 and Figure 20 show improved thermal insulation measures where the insulation is brought to the existing window and the window wall, see Figure 20.

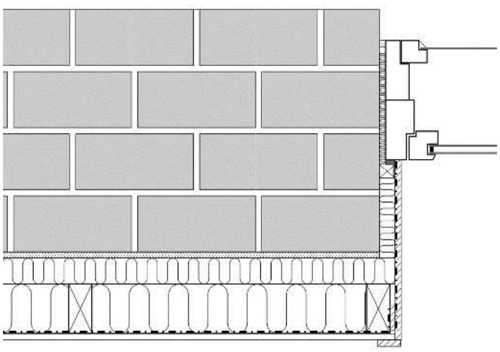

Figure 18. Horizontal section of the joint between the loadbearing exterior wall and the window after *improved thermal insulation measures.*

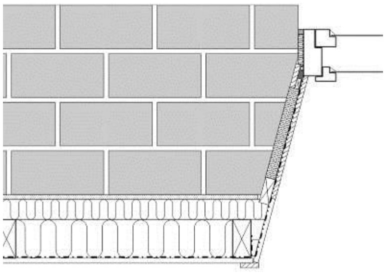

Figure 19. Horizontal section of the joint between the loadbearing exterior wall and the window after *improved thermal insulation measures*.

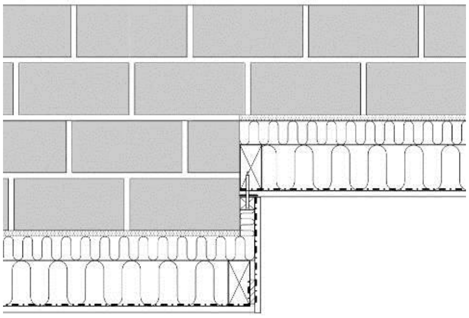

Figure 20. Horizontal section of the joint between the loadbearing exterior wall and the window wall after improved thermal insulation measures.

Improved thermal insulation measures of the horizontal partition towards the basement is relevant if the basement is cold. Improvements of the vertical section is carried out by blowing loose-fill mineral fibre insulation into the cavity between the timber beams, see Figure 21 and Figure 22. The cavity allowed 100 mm mineral fibre insulation.

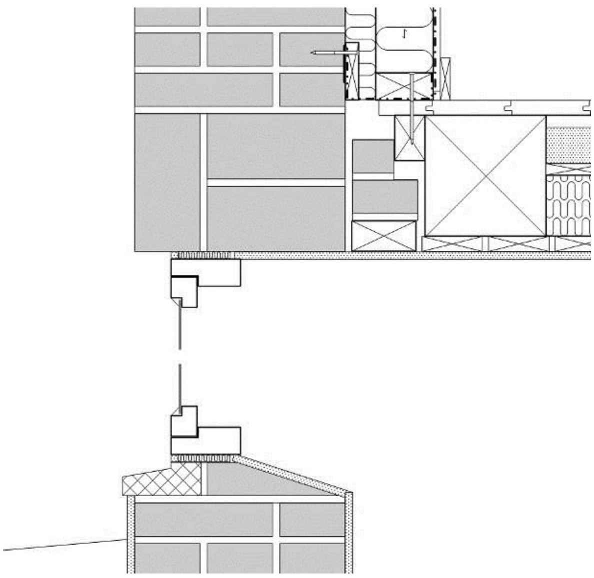

Figure 21. Horizontal partition by timber beams towards the basement at the window wall. An improved thermal insulation measure is carried out by blowing loose-fill mineral fibre insulation material into the cavity between the timber beams underneath the clay infill.

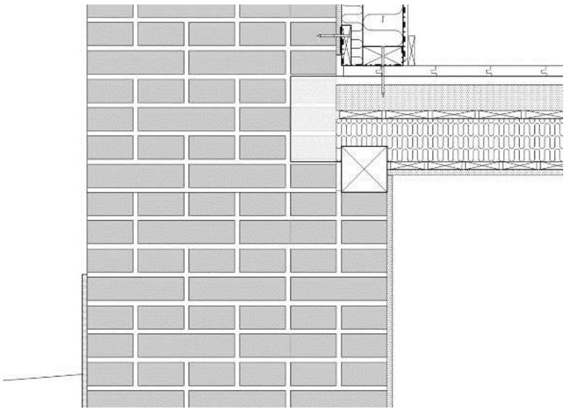

Figure 22. Horizontal partition by timber beams towards the basement at the load bearing wall. An improved thermal insulation measure is carried out by blowing loose-fill mineral fibre insulation material into the cavity between the timber beams underneath the clay infill.

An improved thermal insulation measure of the horizontal partition towards the basement is not relevant if the basement is warm, heated by uninsulated and poorly insulated installations for heating. However, if the basement is warm it might be a good idea to increase the thermal insulation of the basement, see Figure 23 and Figure 24.

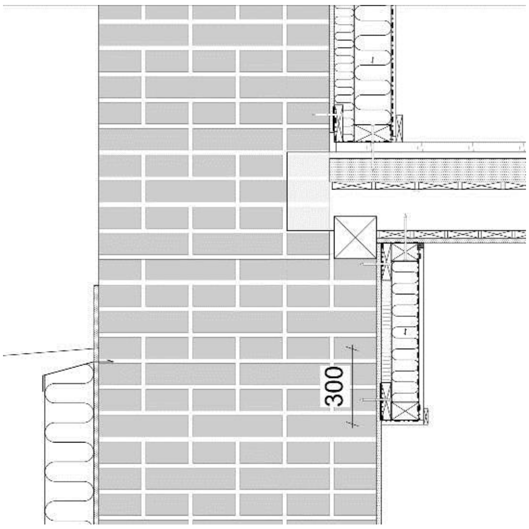

Figure 23. Vertical section of the loadbearing wall in the basement after improved thermal insulation measures.

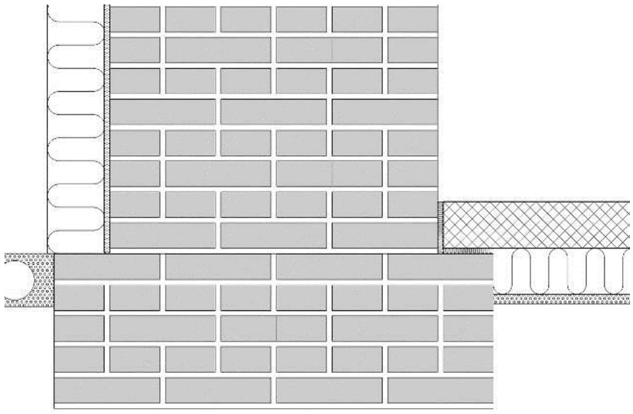

Figure 24. Vertical section at the base of the loadbearing wall in the basement after improved thermal insulation measures.

B) 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 25 to Figure 27 are the original construction. Figure 28 to Figure 34 are with measures increasing the thermal insulation of the thermal envelope.

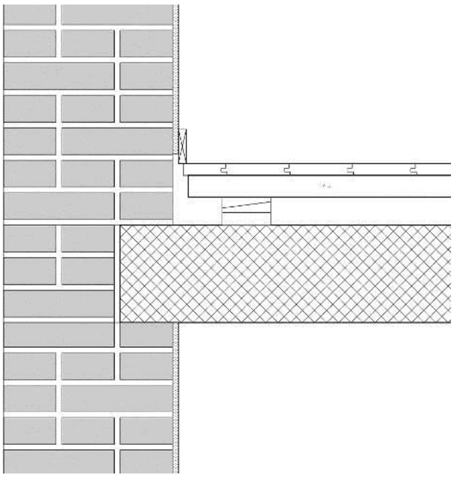

Figure 25. Vertical section of the joint between the exterior loadbearing wall, which is the facade, and the horizontal partition. The exterior wall is a solid brick wall. The concrete deck reach into the brick wall.

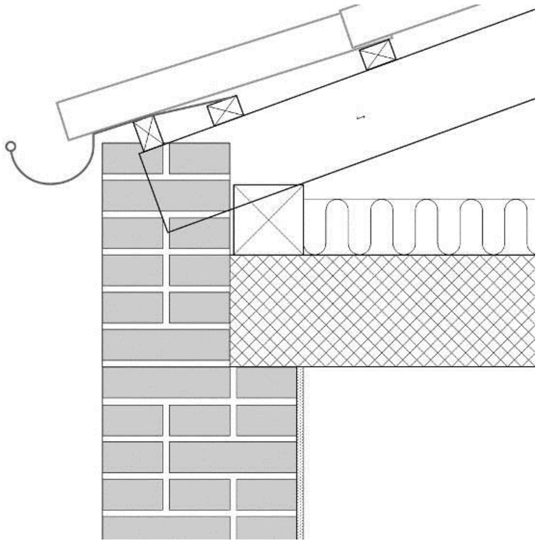

Figure 26. Vertical section of the joint between the base of the roof and the loadbearing exterior wall.

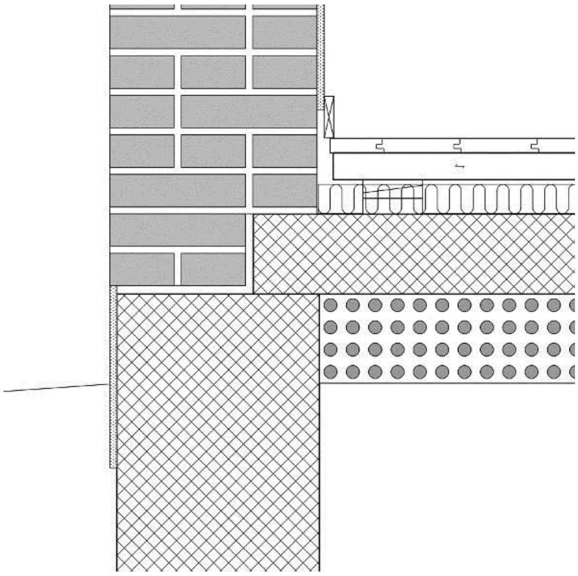

Figure 27. Vertical section at the base of the loadbearing exterior wall placed on a foundation of concrete.

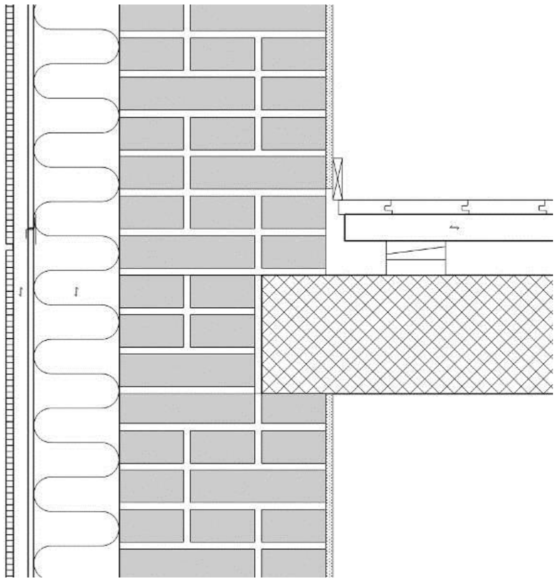

Figure 28. Vertical section of the joint between the horizontal partition and the loadbearing exterior wall after improved thermal insulation measures.

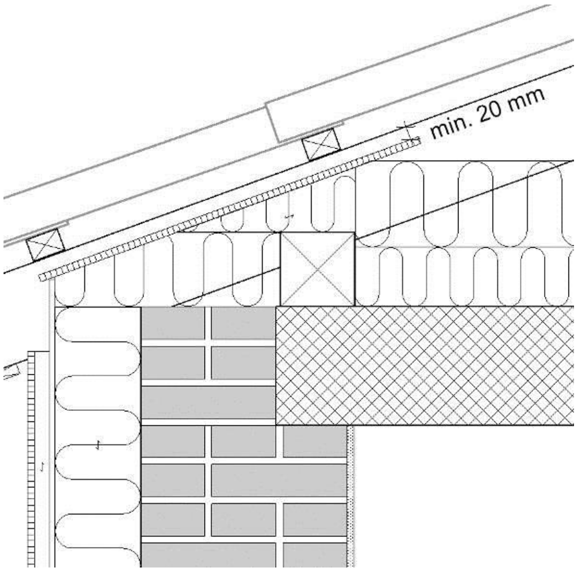

Figure 29. Vertical section of the joint between the base of the roof at the loadbearing exterior wall after improved thermal insulation measures.

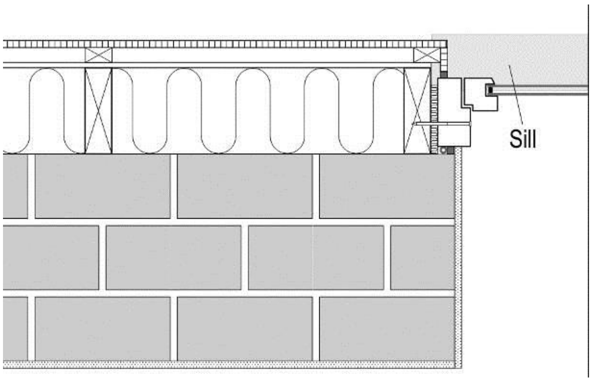

Figure 30. Horizontal section of the joint between the loadbearing exterior wall and the window after improved thermal insulation measures. The window has been replaced.

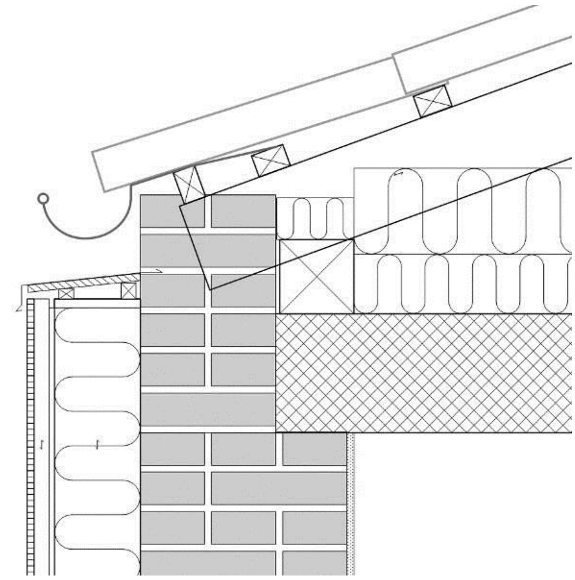

Figure 31. Vertical section of the joint between the base of the roof at the loadbearing exterior wall after improved thermal insulation measures.

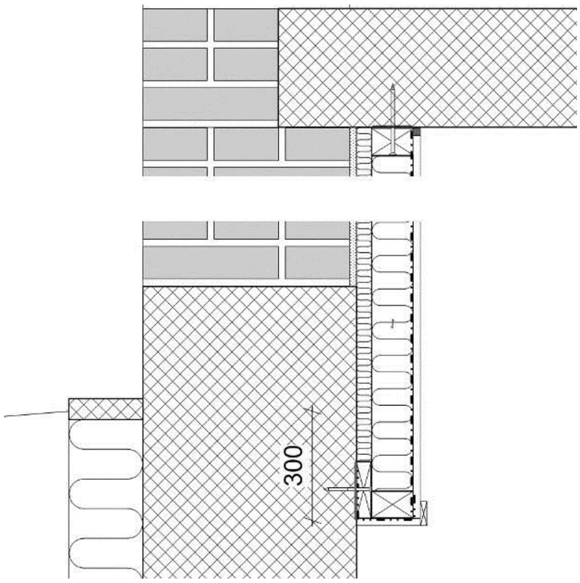

Figure 32. Vertical section of the load bearing wall in the basement after improved thermal insulation measures.

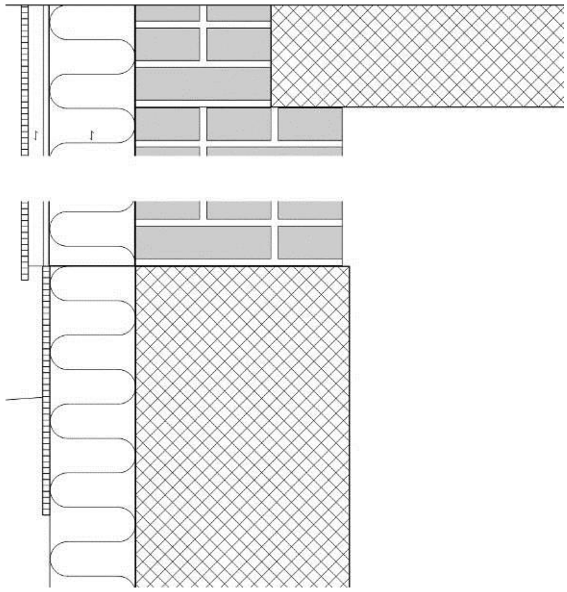

Figure 33. Vertical section of the load bearing wall in the basement after improved thermal insulation measures.

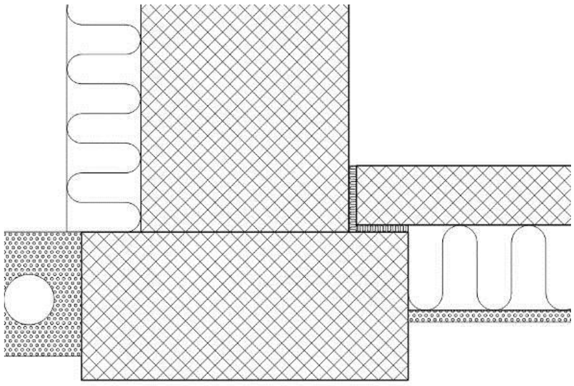

Figure 34. Vertical section at the base of the load bearing wall in the basement after improved thermal insulation measures.

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.

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