

Thermal Building Renovation – Thermal Renovation of Building Components

Abstract

This learning unit describes how the various building components can be renovated really efficiently, depending on the state of the existing building. Selection of materials is explained, challenges regarding the minimization of thermal bridging are discussed and appropriate solutions proposed. Construction details are shown and potential problems (e.g. thermal bridges) are pointed out. In addition, what matters in material selection is discussed.

Objectives

On completing this learning unit students are able to ...

- list and describe measures of thermal renovation
- define thermal bridges
- explain measures to deal with thermal bridges
- name and explain insulation options for individual building components
- select materials for individual building components

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1. How to renovate an external wall

The external walls of a building make up a major part of the heat-transferring surfaces of the building envelope, which is why insulating them is essential for really efficient renovation.

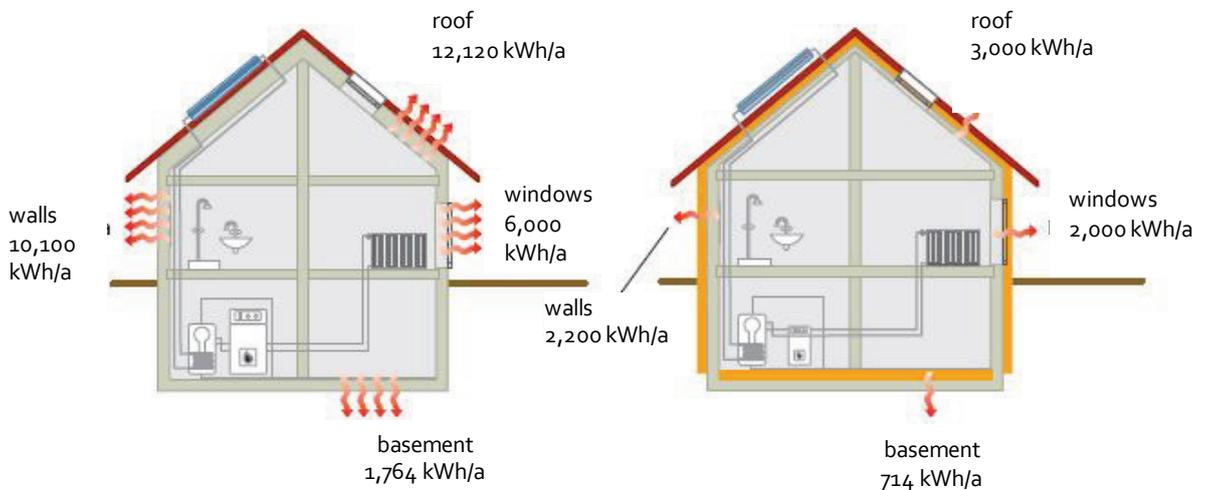


Figure 1: Comparison of heat loss through the building envelope elements before and after proper thermal insulation is installed (source: Deutsche Energie-Agentur, adapted)

External walls can basically be insulated in **three ways**: with **external, cavity wall, or interior insulation**.

Which of these options is chosen, depends, among other things, on the state of the building.

External insulation is the **most common, physically the most straightforward**, and usually also **most effective option**. In this case, insulation is applied to the outside of the external wall.

Physics of buildings

Physics of buildings deals with physical processes in buildings. It is concerned, among other things, with heat, moisture, fire protection and sound, and serves the purpose of avoiding structural damage.

If the existing external wall is **double**, **cavity wall insulation** can be fitted in the space between the two walls.

Interior insulation is an option primarily used **for listed buildings**, the façade of which must not be changed. In this case, **insulation is applied to the inside of the external wall**, i.e. indoors.

1.1 External insulation with external thermal insulation composite systems (ETICS)

External thermal insulation composite systems (ETICS) consist of an insulation layer bonded and/or anchored to the base and a rendering which is usually made of plaster with fabric lining and a finishing coat.

ETICS are mostly supplied by producers as a system solution, which means that insulation material, mounting and finishing coating are matched to each other.

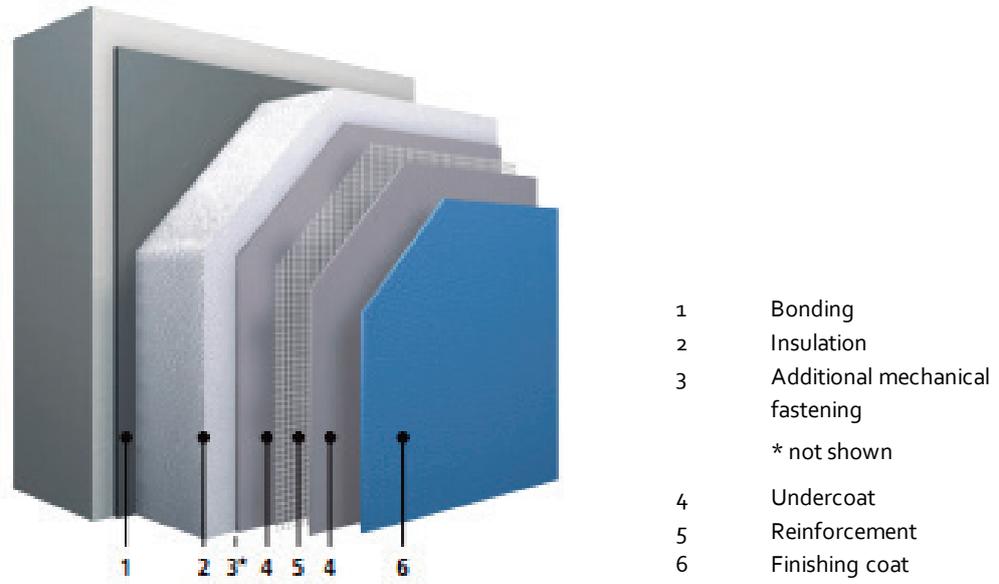


Figure 2: Structure of an ETICS (source: Sto SE & Co. KGaA, adapted)

For a **highly efficient external insulation**, insulation layers **20 to more than 30 cm thick** are technically feasible. In some circumstances, however, this might make applying the insulation more expensive. Despite somewhat higher investment costs, thick layers of insulation pay off via reduced heating costs.

In addition to reducing the heating energy requirement, external insulation also solves hygrothermal problems: Because of the higher temperatures on the interior surfaces, condensation and mould formation are avoided (given an insulation layer approx. 16 to 20 cm thick).

1.1.1 Materials for ETICS

ETICS are available with various different materials, such as insulation foams, synthetic mineral fibres, mineral foam panels, plant-based insulation materials and vacuum insulation.

Depending on the existing substrate, various anchoring systems can be used for external insulation. On flat, clean masonry insulation panels can be bonded. Where renovation involves old plasterwork, the panels should/must – depending on legal regulations – also be anchored.

1.1.2 Installation practice with ETICS

The existing surface must always be examined before an ETICS is installed. Whereas difficulties do not normally arise in the case of new buildings, for renovation work it is essential to **investigate the old plaster** which the insulation is to be bonded to, for example to identify cavities.

Testing adhesive tensile strength is a way to determine whether anchoring is necessary.

During installation it is important to fasten and bond the elements exactly as laid down for the system. **Implementation details must be checked with care**, especially at the foot of walls, around windows and at the junctions between eaves and fascia.

Thermal bridges in the external wall occur **at all component joints, particularly with protruding elements** which are not thermally decoupled, such as balconies or canopy roofs.

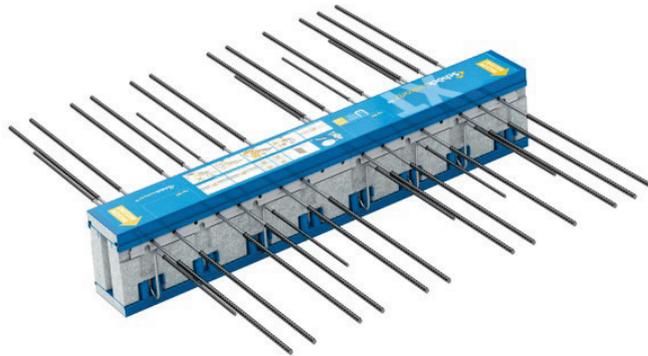


Figure 3: Load-bearing thermal insulation element for cantilevered balconies (source: Schöck Bauteile GmbH)

If it is not possible to **provide an airtight layer on the inside of the external wall**, this can **also be provided within the adhesive layer of the ETICS**. In this case **adhesive must be applied over the entire surface and must cover cracks properly**. In addition, the joints between plaster and openings (e.g., windows and doors) must be made with care and be airtight throughout.

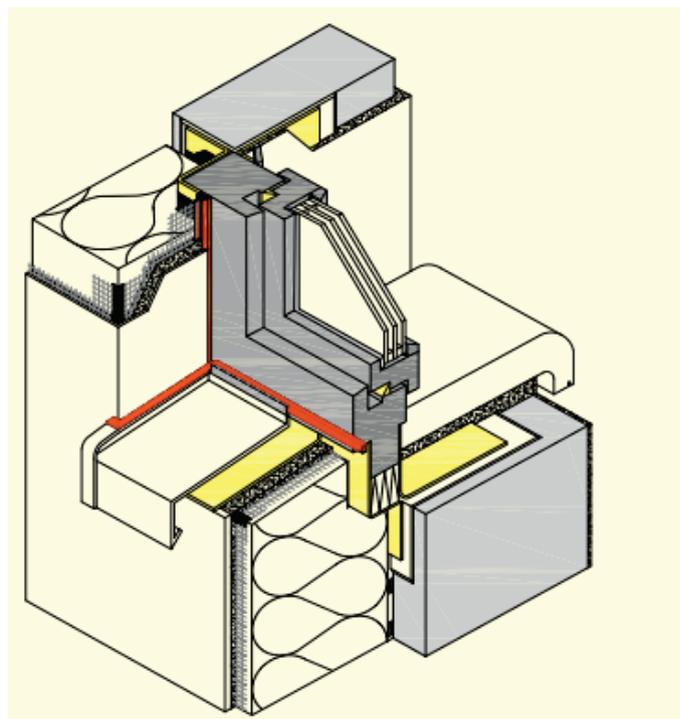


Figure 4: Detail showing a window sill and insulation (source: Sto SE & Co. KGaA)



Figure 5: Joints between external insulation and windows must be implemented with care (source: Schulze Darup)

1.2 External insulation with curtain walls and cavity wall insulation

Curtain walls consist of an insulation layer mounted on the outer face of the load-bearing external wall, **and façade panels** mounted externally, usually with an air space behind. This requires an anchoring system, which can be implemented in various ways and which should have the least possible thermal bridge effect. Curtain walls can also be produced as pre-fabricated timber elements.

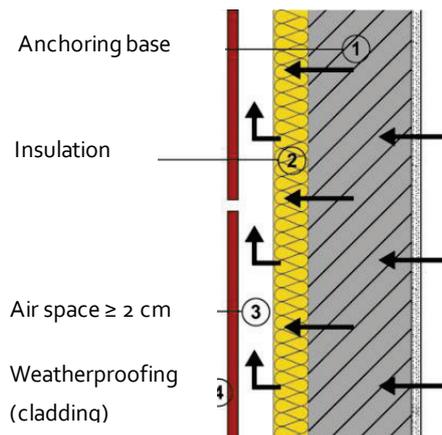


Figure 6: Structure of a façade with air space behind (source: www.FVHF.de, adapted)

Video on building a curtain wall:

<https://youtu.be/23zRoOuszxo>

Cavity wall insulation involves a special form of curtain wall in which a second, exposed masonry shell is provided in addition to the load-bearing masonry and the external insulation. The outer shell is usually secured with stainless steel anchors.

1.2.1 Materials for curtain walls

The great advantage of curtain walls is the free choice of materials. This applies both to the insulation, which can take the form of mineral insulation panels, foamed panels, or even loose-fill insulation if an outside boundary layer is provided at the wind barrier in front of the air space. This means that almost all insulation materials, especially those made from renewable raw materials, can be used. The same applies to the curtain wall itself: any option can be chosen for architectural or functional reasons, be it timber, timber-based materials, metal, ceramics or glass materials.

With **cavity wall insulation** a **distinction** has to be made **between installation during construction** and **subsequent injection into an existing cavity**. Whereas there is a rather large selection of materials for new constructions, only **water-repellent insulation materials** (including hydrophobic materials made water-repellent through treatment) **should be used for injecting**, because moisture can affect the space between the walls.

1.2.2 Installation practice with curtain walls

This system has the **advantage** that it can be **employed in all cases**; in renovating a building it is easy to cope with damage to and irregularities in the façade. Wide freedom of choice applies both to the anchoring system and to the overall installation. **Disadvantages:** the fastening **system involves thermal bridges**, which generally **makes a thicker insulation layer necessary** to achieve a given insulation effect. Also, curtain walls cost from 20 to more than 100 percent more than ETICS. In each individual case one has to check whether a curtain wall will prove to be economically advantageous through savings in maintenance throughout its service life.

In an existing building an uninsulated space in a double wall can be insulated subsequently. **It is important that the cavity is at least 5 cm wide everywhere and can be filled up with insulation material completely**, in order to avoid thermal bridges as much as possible. Because there is usually room only for thin layers of insulation in the case of cavity wall insulation, the insulation effect is necessarily less than with external insulation. Cavity wall insulation is thus rather selected if the existing building requires this (as is the case with listed buildings).

Tip

From the point of view of the physics of buildings it is a good idea to supplement cavity wall insulation with interior insulation.

1.3 Interior insulation

Interior insulation is a possible choice for listed buildings or buildings whose façade must not be changed for aesthetic or other reasons, so that external insulation is not an option.

Compared to external insulation, interior insulation is trickier as regards the physics of buildings, and **less of an insulation effect** can be achieved. Apart from physical considerations, insulation thickness is limited because living space is decreased by insulation on the inside.

1.3.1 Materials for interior insulation

Insulation materials open to diffusion (e.g. those based on minerals or plants) **make sense here**, to **avoid moisture** collecting and mould developing within the insulation, since moisture can escape. **For plasterwork, too, materials open to diffusion must be used** (e.g. clay or lime plaster).



Figure 7: reed and lime plaster can be used for interior insulation open to diffusion (source: GrAT)



Figure 8: Interior insulation with panels open to diffusion (source: ISOTEC GmbH)

If materials not open to diffusion are used, an airtight vapour barrier has to be installed on the inside. This has to be made with great care in order to avoid flaws (joints, leaks, cracks) and resulting damage from moisture.

If the physics of the building are favourable, it is possible to use high-efficiency insulation materials such as aerogels or vacuum insulation.

What is a vapour barrier?

A vapour barrier is a foil with a defined resistance to water vapour diffusion, which prevents the moisture content of indoor air from penetrating thermal insulation in a building.

1.3.2 Installation practice with interior insulation

Interior insulation is challenging in terms of the physics of buildings. Because, in contrast to external insulation, the external wall is not heated from the inside, the **dewpoint** is shifted further inwards and is now located between warm insulation layer and cold external wall.

At this dewpoint there is a risk of moisture condensation and, as a consequence, mould developing. That is why, where interior insulation is employed, an experienced specialist should be consulted about the physics of the building.

What do the terms dewpoint and condensation mean?

Dewpoint is the term for a temperature threshold below which water vapour is precipitated (unchanged pressure assumed).

The term **condensation** is used if warm indoor air penetrates a building component during cold weather, it cools down on its way through the structure, and water vapour in the air can condense out as a liquid.

In most cases very effective insulation with U values between 0.35 and 0.2 W/m²K can be achieved. The first essential is to dimension the insulation etc. to be on the safe side in terms of physics, and a diffusion calculation should establish that it cannot lead to damage from moisture. Second, **air flow around the insulation must not be possible**; instead, the insulation materials must adhere to the entire surface of the external wall. Above all, joints between intersecting ceilings, interior walls etc. must be handled appropriately.

Connections must be planned in detail and implemented accurately! Wall connections and reinforced-concrete ceilings should be provided with flanking insulation, e.g., with insulation wedges, in order to reduce thermal bridges towards the external wall. **With timber beam ceilings it is necessary to seal the beam ends within the insulation layer airtight, so as to avoid outward convection of moist air.**

To cope with thermal bridges at the **junction between interior insulation and basement ceiling**, the basement ceiling receives additional insulation on top (instead of underneath – the usual arrangement), so that interior insulation and basement ceiling insulation form a continuous layer.

At **windows**, too, the interior insulation and the insulation of the window recess should form a continuous layer.

The airtight layer (plaster or vapour barrier) must be inside the interior insulation.

Basically, **convection is the major cause of structural damage to interior insulation**, because if warm, moist indoor air passes through the structure and cools down on the way out, water vapour condenses out. Another important aspect to consider is whether the structure is **watertight to driving rain**. If more moisture intrudes due to the weather, this will probably result in structural damage.

As an additional measure it may help to supply warmth to the room over the full length of the internal insulation, so that the temperature of vulnerable areas is raised somewhat. It always makes sense to **combine interior insulation with fan-based ventilation systems**;

the constant supply of fresh air ensures that indoor air moisture is kept at a low level – a great advantage with respect to diffusion and convection.

Background ...

... on vacuum insulation

For special conditions, vacuum insulation is a possible alternative, achieving high insulation values with a compact structure. For vacuum insulation, the points mentioned above are of particular importance: no driving rain, reduction of thermal bridges at junctions between building components, very careful execution of bonding, and airtightness. The vacuum insulation must not be pierced through – this means that anchors and other penetrations have to be planned and carried out with great care. Vacuum insulation is a good choice for areas which are safe in terms of building physics, such as non-frame structures with double walls or an external wall unaffected by driving rain. As opposed to this, structures with timber penetrations, such as timber beam ceilings, cause problems and require more elaborate planning.

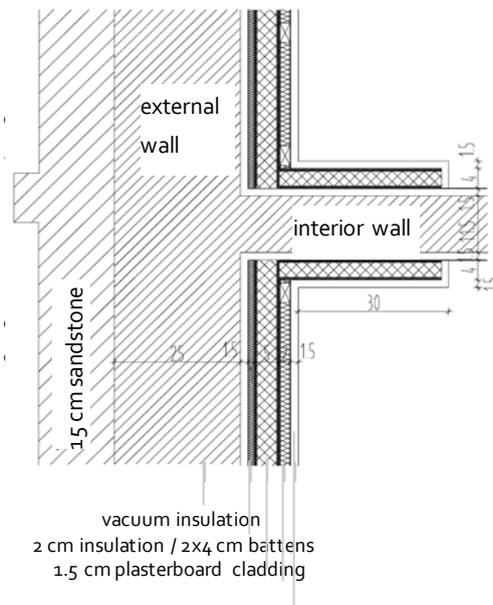


Figure 9: Interior insulation at junction of external and interior wall, with insulation strips or wedge along intersecting interior wall to reduce thermal-bridge effect (source: Schulze Darup, adapted)

2. How to renovate a roof

Roof insulation can be 25 to 40 cm thick. The **exact type and thickness** of the insulation **depend**, among other things, **on the existing building**. Older buildings have either slanted roofs (trussed), mansard roofs (also trussed) or flat roofs.

For insulating **rafter roofs**, there are the options of over-rafter, between-rafter and below-rafter insulation, or two or three of these options are combined in order to achieve the thickest possible insulation.

There are various ways of insulating rafter roofs: **doubling, attaching thick planks laterally, (half) I-sections or suspension**. If additional weight is put on the roof structure, structural limitations must be taken into account and/or a structural engineer must be consulted.

For **over-rafter insulation, the roof structure is doubled upwards**. To do this the roof deck must be removed. Over-rafter insulation is thus an option if the roofing is to be replaced anyway and if the roof structure is strong enough.

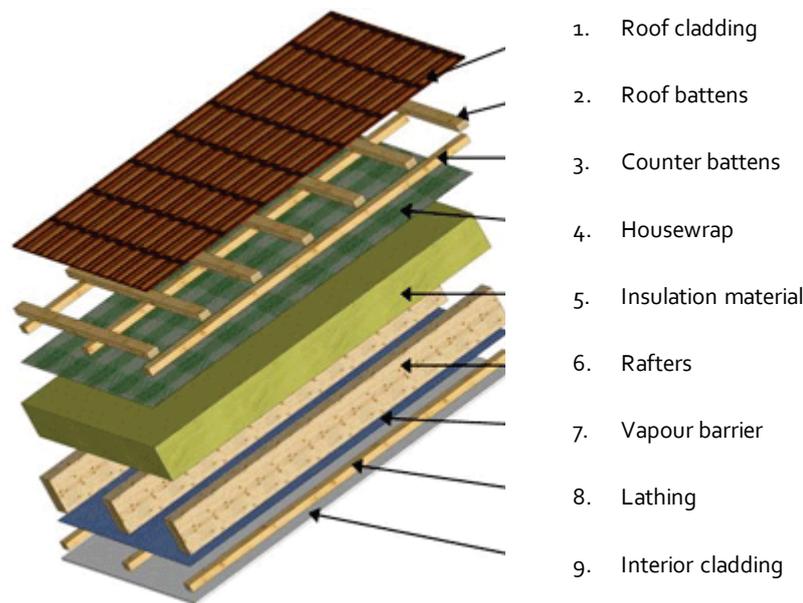


Figure 10: Example of a roof structure with insulation over rafters (source: www.Holzfragen.de, Sachverständigenbüro für Holzschutz Hans-Joachim Rüpke / Dr. Ernst Kürsten Hannover, adapted)

For **between-rafter insulation, insulation is installed between the roof rafters**. This method alone is usually insufficient for really efficient renovation, because many existing buildings have rafters only about 14 cm thick.

Below-rafter insulation is installed from inside, which is why this option is advisable if an attic conversion is planned anyway. The rafter structure is doubled/suspended downwards, which decreases the space inside. It makes sense to combine it with between-rafter insulation. If the roofing is subsequently replaced, doubling upwards too will be possible.

The goal is to achieve the thickest possible insulation layer, with U values between 0.18 and 0.10 W/m²K; ideally the different methods of rafter insulation should be combined.

Flat roofs are renovated through doubling. Either the new insulation layer is placed on the old insulation layer, or the entire insulation is replaced. **Either a cold-roof structure** with an extra level of air circulation next to the sealing layer, **or a warm roof** with bitumen or foil sealing can be implemented.

2.1 Materials for roof insulation

The choice of materials depends on actual requirements in a given case. For timber roof structures blanket insulation or loose-fill insulation is a good idea. In many cases, mineral fibre panels or loose-fill cellulose insulation are used.

For over-rafter insulation and flat-roof insulation solid panels are advantageous.

2.2 Installation practice for roof insulation

In roof structures, too, thermal bridges must be eliminated as far as possible. In the roof insulation these can arise at eave and bargeboard junctions, at the intersection of gable and interior walls, chimneys and other structures on the roof.

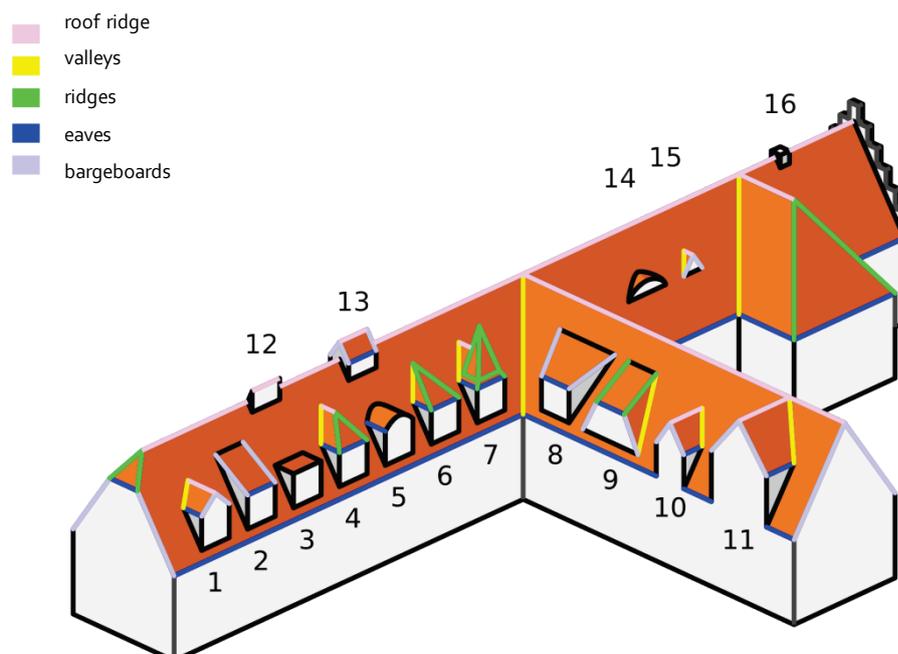


Figure 11: Diagram of a roof, showing different edges (coloured lines) and types of dormers (numbered 1-16) (source: Roland Bergmann Dipl. Ing. (FH) Architekt; https://de.wikipedia.org/wiki/Ortgang#/media/File:Dachgauben_Dachkanten_de_Text.png, adapted)

Point thermal bridges can also occur, for example with satellite dish mountings, which interfere with the continuous insulation layer.

In between-rafter insulation, thermal bridges are caused by the rafters within the insulation layer, which must be taken into account for calculating the U value. In below-rafter insulation, thermal bridges can occur where walls extend to the rafters and thus into the insulation layer. Over-rafter insulation causes fewer problems with thermal bridges.

The airtight level is always implemented on the warm side, i.e. the inside of the insulation. For over-rafter insulation this is easy; but for between-rafter insulation, which is installed from above, it is more difficult, because a foil is laid over and between the rafters,

and there is a risk of condensation there. In below-rafter insulation, walls which reach the rafters may possibly interfere with the airtight level.

If the roof structure is made impermeable to diffusion, a complete air seal is vital for the structure to function properly.

If the roof is renovated on its own to start with, the details of transitions and junctions should still be prepared properly with a view to future renovation measures. For example, sufficient roof overhang beyond the exterior walls can be prepared at eaves and bargeboards, where the external wall insulation can later join on. From a design perspective, care should be taken at this point that the final result be harmonious in detail. Thermal bridges at these transitions must of course be thought over in advance.

3. How to renovate a top-floor ceiling

The top-floor ceiling is a building element which can be insulated easily and with great effect. **Insulation is installed above the ceiling, if possible.** If the attic is not in use, a thick insulation layer can be applied at low cost, e.g. by injection. But there are also efficient insulation systems with a walk-on covering. **Insulation below the ceiling is possible in principle, but involves a more elaborate design and greater cost,** and is more difficult in terms of the physics of buildings, because it then corresponds to interior insulation and presents the same problems. This option is thus rather the exception.



Figure 12: screed over the insulation of a top-floor ceiling (source: Schulze Darup)

3.1 Materials for top-floor ceiling insulation

It makes a difference whether reinforced-concrete ceilings and timber beam ceilings are in place.

- **Reinforced-concrete ceilings:** insulation is usually installed over the ceiling. Any loose-fill materials, blanket insulation and panels can be used.
- **Timber beam ceilings:** basically the same applies here, but insulation can also be installed between the beams. However, one must check whether the additional expense is worthwhile. The structure must be made airtight, to avoid condensation in the insulation layer.



Figure 13: insulation of a timber beam ceiling (source: Schulze Darup)

3.2 Installation practice with top-floor ceiling insulation

Insulation above the top-floor ceiling can be made either walk-on or non-walk-on.

- **Walk-on:** a screed or panel covering is laid on top of the insulating structure (e.g. consisting of insulation panels). There are also inexpensive insulation systems with loose-fill insulation and a walk-on covering on bar spacers.
- **Non-walk-on:** if there is no need for a walk-on covering, any form of insulation can be applied; in many cases loose-fill insulation ought to be the most sensible solution. In any case a cover layer has to be laid on top, to ensure a draught-proof seal and prevent particulates from the insulation material escaping into the ambient air.

Especially with timber beam ceilings, **an airtight level must be implemented beneath the insulation layer**. The reason for this is to avoid air flow from the interior through the ceiling, so as to minimize the risk of condensation in the structure, which could lead to the beams rotting.

Note that **thermal bridges** can arise when a top-floor ceiling is insulated:

- at eave junctions
- at partition walls
- at staircases
- at penetrations, e.g. chimneys.

4. How to renovate a basement ceiling / floor slab

The base of a building's thermal envelope can be insulated in various ways. If an **unheated basement** exists, **insulating below the basement ceiling** is advisable. If the **basement ceiling is not high enough**, **insulation** can be laid **on top of it** instead. In **buildings without any basement** or with a heated basement the only option in most cases is to install the **insulation on the floor slab**.

4.1 Materials for basement ceiling / floor slab insulation

For insulation **below the basement ceiling, insulation panels are used**; they can be bonded, anchored or suspended. For this application a variety of materials are available. Care should always be taken to use materials that are as resistant as possible to increased air humidity. **Many materials are suitable both for insulation above the basement ceiling and for insulation above the floor slab** in buildings without a basement. **First of all waterproofing must be applied on the floor slab.** Any insulation material commonly used under screed can be chosen, such as foam panels, rock wool, wood fiber panels and other biogenic insulation materials. However, one must **bear in mind that if moisture gets in**, for example after a water-pipe burst, the **material may be soaked**; this is why **it is advisable to choose materials which are resistant to soaking** and which recover satisfactorily if dried out in one of the ordinary processes. Any material which can rot or is sensitive to moisture are not really suitable for such applications.

If an uneven floor is to be insulated, a levelling fill in addition to the insulation makes sense. Finally screed is laid over the insulation.

4.2 Installation practice with basement ceiling / floor slab insulation

Insulating the base of a building poses a special challenge. Inevitably the walls rising from the base act as thermal bridges. The only possibility is to extend the pathway of thermal outflow by choosing the right arrangement, thus reducing thermal bridging.

4.2.1 If there is a basement

Insulation is in most cases applied below basement ceilings by bonding, anchoring or suspending insulation panels.



Figure 14: a basement ceiling insulated from below. Here the pipes are laid in the insulation layer, i.e. within the insulated building envelope (source: Schulze Darup)

In general, a thickness of 15 to 20 cm is recommended for basement ceiling insulation. In some cases the basement ceiling may not be high enough. Then a solution would be to combine insulation below the basement ceiling and insulation below the screed on the ground floor.

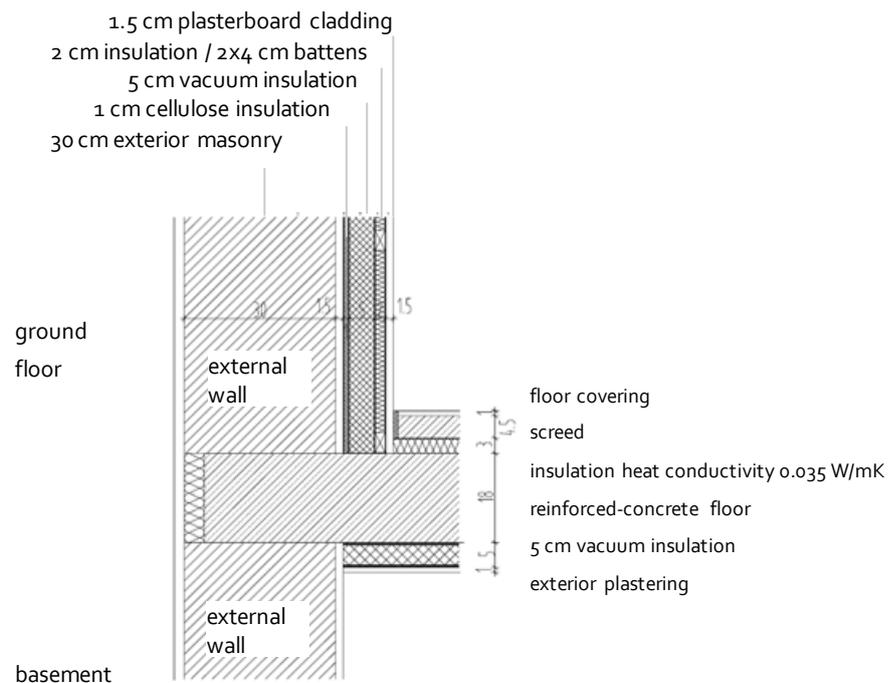


Figure 15: Insulation above and below the basement ceiling (source: Schulze Darup, adapted)

If the floor itself is renovated, a dry floor can be installed, making thicker insulation possible. The whole structure must always be checked for condensation, though.

Background on ...

... high-efficiency insulation materials

Another option with low ceilings is to use high-efficiency insulation products such as vacuum insulation, which combines maximum efficiency with minimum thickness, due to its very low coefficient of thermal conductivity, $\lambda = 0.006$ to 0.008 W/mK; it can achieve passive house quality with an insulation layer around 6 cm thick.

As regards insulating the floor slab, ceiling height may not permit a thick layer of insulation, either. Here again vacuum insulation is an alternative, because the material is protected beneath the screed.

If insulation is installed only above the basement ceiling, the insulation layer behaves like an interior insulation. As such, it must be made airtight in order to avoid the associated problems of **condensation** and mould development. In this case the airtight level is above the insulation and should be made to extend continuously to the interior plasterwork of the ground floor walls.

Thermal bridges in the basement area occur **where load-bearing external walls penetrate the basement ceiling insulation, and at interior walls or supports.**

These thermal bridges can be defused by means of flanking insulation (similar to insulation wedges for interior insulation) that extends the insulation layer of the ceiling over

the walls. The flanking insulation should extend 30 to 50 cm and should be roughly 3 to 5 cm thick. The dimensions actually needed can be worked out in a thermal bridge calculation.

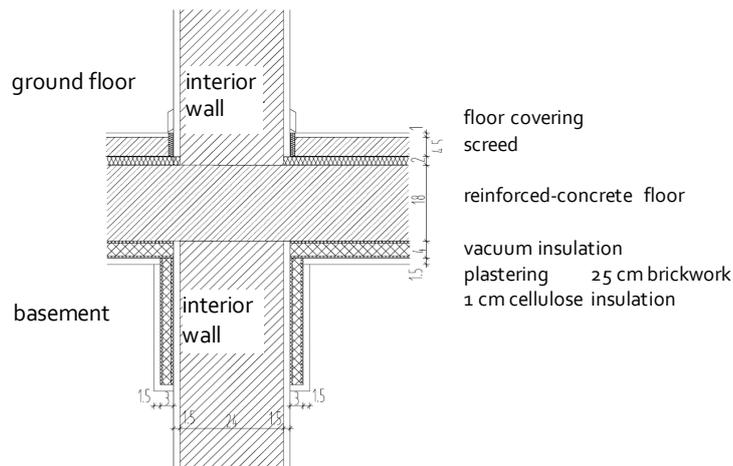


Figure 16: Flanking insulation in the basement (source: Schulze Darup, adapted)

Alternatively the insulation is installed **on the ground floor beneath the screed**. However, this option costs more and thus should be chosen only if the screed is to be renovated anyway. One must bear in mind is that the **floor level is raised by the additional insulation**. With timber beam structures additional insulation can also be installed between the beams.

4.2.2 If there is no basement

In this case the floor slab is insulated beneath the screed.

Important: A seal against rising damp must be installed before the insulation layer is applied.

Another option is to remove the floor slab and excavate deeper, so as to install insulation from below, but this is an extremely costly measure. As an alternative, installing perimeter insulation around the foundations of the building and extending this insulation as far down as possible should be considered.

The resulting losses must be calculated by simulation. As long as the water table is not close to the surface, all-round perimeter insulation can achieve a very good overall result with large floor slabs.

5. How to renovate windows and doors

5.1 Windows

There are **basically two ways** to reduce heat losses when windows are renovated. Either the **whole window is replaced** with a high-efficiency window, **or the window is renovated and a new inner window fitted**, so that its appearance is unchanged and the inner window reduces heat loss. **This is an option for windows in listed buildings** or windows of high aesthetic quality. For listed buildings box-type windows are available with the following configuration: the outer window is single-glazed with filigree frames as per listed-building requirements, while the inner window has triple glazing for excellent insulation.



Figure 17: windows installed during renovation (source: Schulze Darup)

5.1.1 Materials for windows

The choice of window materials depends on various planning requirements. The most suitable solution for the case in question must be found.

The following frame materials are available:

Wooden windows: frames made from wood or wood composites, in some cases combined with insulation materials to achieve a good U value for the frame.

Wood/aluminium windows: wooden windows combined with weatherproof aluminium cladding. An insulation layer can be inserted between the wood and the aluminium at low cost so that a highly efficient frame is achieved.

Plastic windows: frames of high thermal quality can be produced from extruded plastic, usually PVC. If the frame material is enhanced with reinforcing fibre, the frames can be produced at low cost to high thermal standards; insulating profiles can be inserted where a steel insert has traditionally been used to provide mechanical strength.

Metal windows: mostly made of aluminium, they are of high quality and durable, if implemented well. These frames with very good U values have become available only in recent years.

5.1.2 Installation practice for renovating windows

Inexpensive windows can be produced with U_w values between 0.75 and 0.95 W/m^2K . The triple glazing incorporated generally has U values of 0.5 to 0.7 W/m^2K combined with a composite edge seal of high thermal quality; and then insulated frames with U values of 0.65 to 0.8 W/m^2K are needed.

For high-efficiency renovation not only the quality of the actual windows is important, but also how they are installed!

In order to preserve the original appearance and avoid thermal bridges, the windows should be shifted outwards by the thickness of the wall insulation. Together with an increased frame depth of 10 to 12 cm, this makes it possible to minimize thermal bridging – **the insulation should enclose the frame as far as possible. In addition airtight masking is necessary,** joining window and airtight level directly; this can be implemented against the indoor plasterwork. In principle an airtight level is feasible, too, for instance in the ETICS adhesive layer.



Figure 18: masking around the windows to tie in with the airtight level in the ETICS adhesive layer. Insulation is laid around the frame in order to minimize thermal bridging (source: Schulze Darup)

As a general rule renovating **the windows should always be planned in conjunction with renovating the external walls**, so as to avoid physical problems. If new airtight windows are installed but the external walls are not insulated, humid indoor air can condense on the cold walls and lead to mould developing. This particularly concerns corners in bathrooms, kitchens and bedrooms, especially behind furniture and curtains.

5.2 Doors

In larger buildings entrance doors make up only a small part of the building envelope. In smaller buildings (e.g. single-family houses), the door plays a somewhat greater part, which means that good U values are important. In larger buildings, this makes less difference, and the focus should be on functionality, because of the very high frequency of use.

The U_w value of high-quality front doors is about 0.8 W/m^2K . Here it is **important to use doors which combine airtightness** with a satisfactory closing mechanism, so as to avoid ventilation heat loss and cold air being drawn into the stairwell.

Apart from front doors, other doors, such as those to basements or attics, must be implemented to the same standard. Apartment doors in multi-family houses should be airtight, but do not require particularly good U values if the stairwell is part of the heated space within the building.



Figure 19: door suitable for passive house (or nearly zero-energy buildings), installed in a renovation project (source: Schulze Darup)

6. Minimizing thermal bridging and ensuring an airtight seal

6.1 Thermal bridges

Thermal bridges are areas of the building envelope with more transmission heat loss than elsewhere and with lower temperatures on the inside than in the rest of the structure. In the worst case heat loss through thermal bridges can account for up to 30 % of transmission heat loss.

The surface temperature on the inside of the building envelope is lower at thermal bridges than in adjoining areas.

If, when the temperature outdoors is low, the inside surface temperature sinks below approx. 13 °C, water vapour will condense in these areas (assuming normal room temperature and humidity). As a consequence of moisture accumulating, **mould can develop** in these areas.

In addition, thermal bridges increase energy loss. However, there are also “negative” thermal bridges which reduce heat loss in a thermal-bridge calculation. Such “negative” thermal bridges can occur at well-implemented locations because of the geometry of the structure, for example at external corners with all-round insulation. They reduce heat loss

because this calculated from the U values of the various surfaces and from the outside measurements.



Figure 20: mould development in corners where thermal bridges take effect (source: GrAT)

At the planning stage in a high-efficiency renovation project it makes sense, in connexion with calculating the heat energy requirement, to **identify all thermal bridges individually**, with their lengths and coefficients of thermal conductivity, and while doing so to work out local improvements.

One can distinguish between

- **structural thermal bridges** (through building components with differing thermal conductivity, e.g. at the junction between a reinforced-concrete floor and an external wall),
- **geometric thermal bridges** (e.g., at projections and corners) and
- **material thermal bridges** (due to different materials).

The type and frequency of thermal bridges in a building also varies considerably with the **age of the building** and the typical features of construction at that time. Different types of construction all have their typical weaknesses, which often involve thermal bridges.

Calculating heat energy requirement

calculation of Ψ values (psi values) based on EN ISO 10211-1 or -2

psi value (Ψ value) = coefficient of linear thermal conductivity

chi value (χ value) = coefficient of point thermal conductivity

6.2 Airtight seal

If the building envelope is not airtight (whether in renovated or new buildings), i.e. if it has localized leaks, then **warm, humid air moves from the interior through the elements of the building envelope. As this air cools down on its way out, moisture can condense in the elements in question and mould can then develop.**

In addition such localized leaks cause ventilation heat loss, which in turn impairs the insulation effect of the building envelope.

The heat transferring surface of the building must therefore be implemented with a permanent airtight seal.

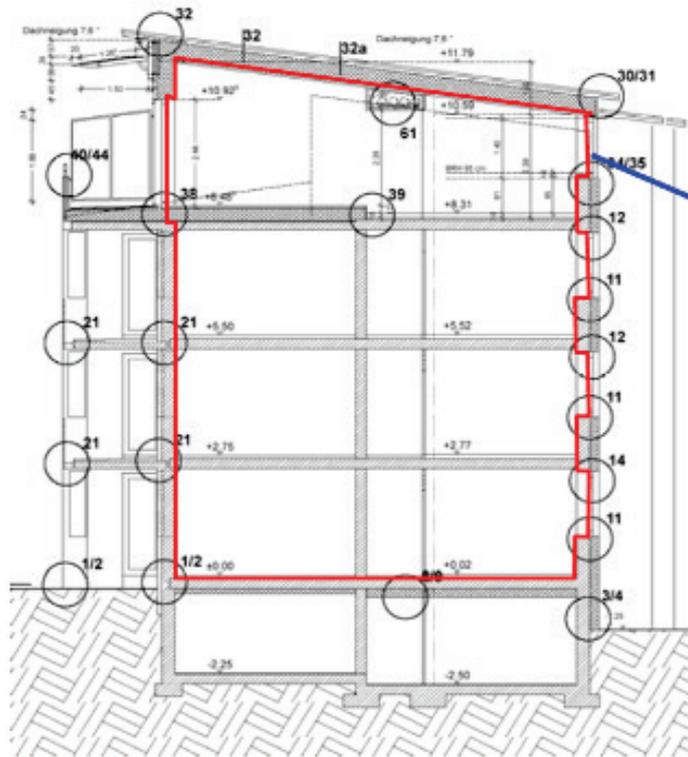


Figure 21: continuous airtight level in a building (source: Schulze Darup)

Typical defects are window and door interfaces, joints between building elements, junctions between masonry and lightweight structures, penetrations for building services and especially conduits and flush-mounted power points for electrical facilities. In all details of implementation the airtight levels must be defined and the actual sealing arrangements specified.

Airtight and draught-proof implementation has the following advantages:

- structural damage is avoided
- the thermal insulation takes full effect
- airborne sound insulation is effective
- ventilation systems are effective
- air quality is improved (due to the ventilation system required)

6.2.1 Blower door test

To check the airtight seal, the so-called "blower door test" is carried out, in which a pressure differential is created using a fan mounted in a blower door installed to achieve an

air seal. At a pressure differential of 50 pascal airflow is measured both at reduced and at increased pressure. The arithmetic mean of the two values is the measured n_{50} value.



Figure 22: blower door test (source: Schulze Darup)

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