# TECHNICAL GUIDELINES

## Building refurbishments

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EU4Energy

Covenant of Mayors
for Climate & Energy

Demonstration Projects
Eastern Partnership

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# 1 Introduction

## 1.1 Background information

The energy consumption for space heating in public, commercial and residential buildings accounts for more than 30 percent of the total energy consumption in most countries of the region, as previous construction and heating methods did not focus on energy efficiency. As a result, a highly inefficient energy use intensifies the impact of rising energy prices on households and public institutions.

The majority of the housing stock, especially in urban areas, consists of pre-fabricated multi-story apartment buildings that are generally of poor construction, badly insulated and maintained and as a result provide a low level of energy efficiency and living comfort. Mostly based on the Russian GOST and SNIP (State Standard and Sanitary Norms and Rules) standards, current construction standards and practices for residential or public buildings or are behind the corresponding European and international standards and not effectively applied in the refurbishment of old buildings and the construction of new buildings.

The characteristic features of the project targeted buildings are:

- Poorly or non-insulated building (walls, roof, basement)
- Thermally inefficient windows and doors
- Infiltration of outside air/water due to leakages

The main objective for thermal refurbishment projects under the framework of the Sustainable Urban Development Project is the development and implementation of a comprehensive high quality refurbishment of the building envelope, which reduces the annual operational costs substantially.

In particular the refurbishment project should meet the following objectives:

- The refurbished buildings shall fulfil energy performance building standards targeting at low energy buildings (substantial reduction of the calculated energy consumption)
- High quality building refurbishments which ensures a long technical lifetime of the building (expected lifetime of the refurbishment measures of more than 20 years)
- The level of the thermal comfort for the building users shall be increased
- The project shall respect all relevant national standards but also western European standards and practices which are relevant for ensuring a sustainable building refurbishment project.

## 1.2 How to use this guide

This guideline was prepared within the framework of the Sustainable Urban Development Project to support public institutions in the development and implementation of the thermal refurbishment of public and residential buildings. This guideline aims at all technical experts who are involved in the development and implementation of thermal refurbishment projects such as energy audit experts, architects, construction experts, etc.

This guide should provide basic information on the technical requirements for typical construction elements in the order to achieve a high quality thermal refurbishment project. As each project has its specific construction details and materials the recommended approach must be adopted for each project according to its actual needs.

## 1.3 General information

**When is the best timing for implementation of Energy Efficiency measures?**

The thermal refurbishment of buildings often include a package of capital repair measures such as rain water management system, improving the roof, etc. therefore the best timing for EE measures is when capital repair/maintenance measures in a building have to be implemented. Combining necessary capital repair/maintenance measures with the implementation of Energy Efficiency measures is usually the most cost efficient refurbishment approach.

**What kind of measures should be implemented?**

The refurbishment of the building envelope is a cost intensive measure; the expected technical lifetime should be more than 20 years.

The main goal of a thermal refurbishment of a building is to:

1) Reduce the heat transfer through building elements and
2) Seal the building (no uncontrolled ventilation any more → effect on the ventilation of the building)

The building elements **roof – external walls – windows/doors – ventilation** are connected to each other therefore the refurbishment measures have to be considered together. In most of the refurbishment projects the roof, external walls, windows/doors and the ventilation system must be refurbished → comprehensive refurbishment project.

Such a comprehensive refurbishment project requires a substantial investment. In the event that the available financing sources cannot cover such a comprehensive project, it is highly recommended to focus on other energy saving measures which are not that cost intensive but also deliver substantial savings.

**What Energy Saving Measures can be implemented with a limited budget?**

- Thermal insulation of the technical level/top floor
- Thermal insulation of the basement ceiling
- Refurbishment of the internal heating system
- Insulation of pipes in the boiler house/ basement
- Improving the boiler house
- Installation of a solar system for preparing domestic hot water (the roof must be in a good technical condition)
- Improving the lighting system

- Implementation of an „Energy Management System“
- Training of employees, technical staff
- Optimising control systems
- Cleaning the basements, and avoid heating of unused spaces

**Estimation of investment costs**

The estimation of realistic investment costs is of utmost importance. The quality of the Sudep projects will be more advanced than the typical national refurbishment project. Therefore cost information from already implemented refurbishment projects can be applied only within limits.

The accuracy of the estimation of the investment costs shall be +/- 30 % during the energy audit phase and +/- 15% during the detailed design phase.

## 1.4 General steps of the project development and implementation

### *1.4.1 Project participants*

When implementing a comprehensive refurbishment project usually many actors need to be involved. The efficient and smooth implementation of a project depends highly on the clear definition of the project roles and responsibilities as well as a good communication between the relevant actors. The following table shows the main actors and their function during the development/implementation of a typical thermal refurbishment project.

| Who | Short | Function |
|---|---|---|
| Municipality (Beneficiary) | MUN | Public authority that implements the project and takes the final decisions. |
| Project Team | PT | Team of experts that supports the Municipality in the project development and implementation. The Project Team is contracted by the Municipality/Contracting Authority. |
| Support Team | ST | Team of external experts that supports the Municipality and the Project Team during the project development and implementation. The Support Team is contracted by the European Commission |
| Contracting Authority | CA | Public Authority that is responsible for tendering and contracting of services and works for the Municipality/Beneficiary. |
| Energy Audit Company | EA Com | Experienced company that provides Energy Audits for public/residential buildings |
| Engineering company | ENG Com | Experienced engineering company that provides the technical design and documents for the authority approvals of the refurbishment project. |
| Construction company | CON | Experienced construction company that is implementing the |

| | | |
|---|---|---|
| | Com | refurbishment project |
| Site supervisor | SITE | Experienced expert who is supervising the implementation works. The Site Supervisor is contracted usually by the Municipality/Contracting Authority |
| Others | | On demand |

### 1.4.2 Project roles

The following figure shows the interconnections of the above listed main actors of a project:

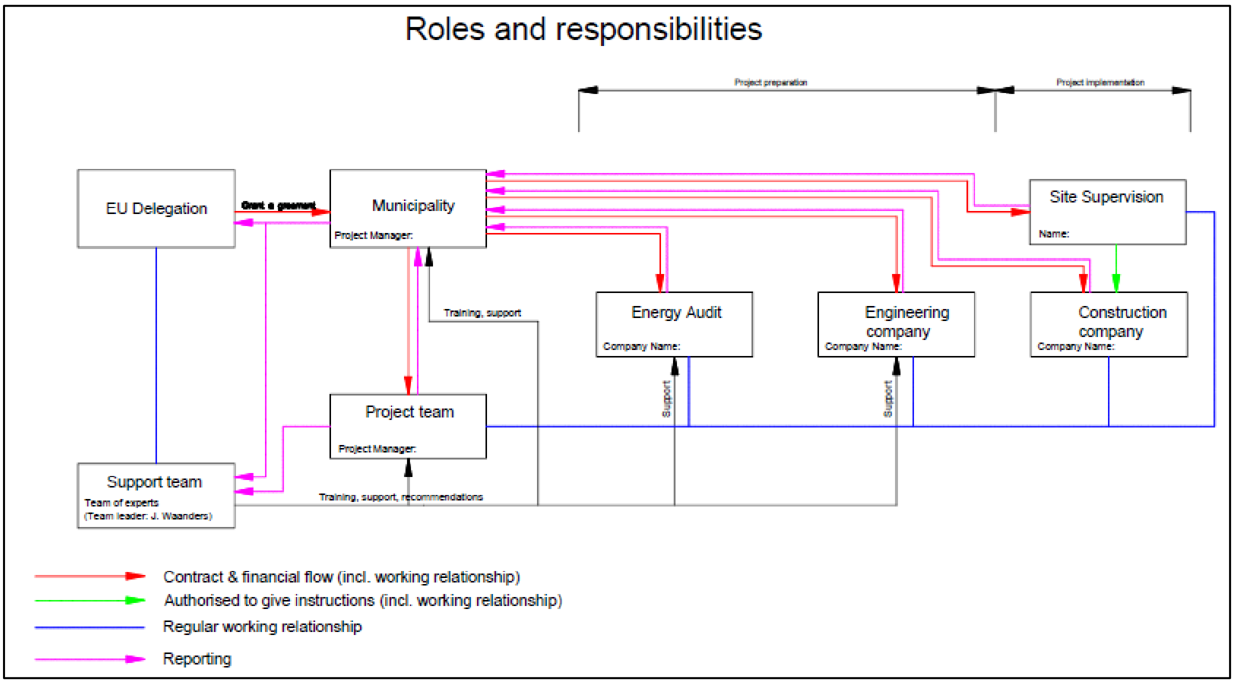



Figure 1: Main actors of the project

### 1.4.3 Project implementation

The implementation of a comprehensive refurbishment project is usually organised in several project phases. Typically, such a project is organised in 8 phases with several activities. The table below tries to outline the project phases/project tasks and the possible duration of the tasks. The duration of a thermal refurbishment project is around 1 and 3 years depending very much on the size of the project and the decisiveness and project management abilities of the Municipality. Please note, that the project financing and approvals from external actors can require additional time.

A typical comprehensive refurbishment project of a public building (e.g. school building) comprising of the refurbishment of the roof, thermal insulation of exterior walls, replacement of windows/doors, thermal insulation of the basement ceiling, refurbishment of the rain water management system, lightning system, concrete sidewalk around the building, building access, ventilation system, etc. and can last up to 2.5 years.

| | Activities | | Year 1 | | | | | | | | | | | | Year 2 | | | | | | | | | | | | Year 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Who | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| **Phase 0** | **Developmant of a project idea** | MUN, PT | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Phase 1** | **Energy Audit** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 1.1 | Tender/contracting of an Energy Audit company | PT, CA | | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 1.2 | Elaboration of the Energy Audit | EA Com | | | ■ | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 1.3 | Decision on EE/RE measures | MUN, PT | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | | |
| **Phase 2** | **Technical design** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 2.1 | Tender/contracting of an engineering company | PT, CA | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | |
| Task 2.2 | Elaboration of the draft final design | ENG Com | | | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | | |
| Task 2.3 | Elaboration of the investment costs/financial analysis | ENG Com, PT | | | | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | |
| Task 2.4 | Decision on EE/RE measures based on financial analysis | MUN, PT | | | | | | | | | ■ | | | | | | | | | | | | | | | | | | | |
| **Phase 3** | **Authority approvals, permits** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 3.1 | Elaboration of documents for the authority approvals | ENG Com | | | | | | | | | ■ | ■ | | | | | | | | | | | | | | | | | | |
| Task 3.2 | Submission of documents and approval of the authorities | MUN, Authorities | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | | | | | |
| Task 3.2 | Elaboration of the final technical design | ENG Com | | | | | | | | | | | | | ■ | | | | | | | | | | | | | | | |
| **Phase 4** | **Tender of an construction company** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 4.1 | Elaboration of the tender documents | ENG Com | | | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | | | |
| Task 4.2 | Launch of the tender documents | CA | | | | | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | |
| **Phase 5** | **Contracting of an construction company** | CA | | | | | | | | | | | | | | | | | ■ | | | | | | | | | | | |
| **Phase 6** | **Implementation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 6.1 | Establish the implementation structure | PT | | | | | | | | | | | | | | | | ■ | | | | | | | | | | | | |
| Task 6.2 | Tender/contracting of a site supervisor | PT, CA | | | | | | | | | | | | | | | | ■ | ■ | | | | | | | | | | | |
| Task 6.3 | Project management/coordination of the implementation | PT, SITE | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Task 6.4 | Implementation | Con Com | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Phase 7** | **Final acceptance** | MUN, PT, SITE, CON Com | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ |

Figure 2: Typical project phases of a refurbishment project

# 2 Thermal Refurbishment of flat roof structures

## 2.1 Background information

Roofs in general are the most exposed building parts. A large share of energy (heat) in a building is lost through the roof. Thermal design is concerned with the flow of both heat and water vapour through the roof construction and their subsequent effect on the performance of the roof and the various components in the system. The technical design needs to consider the amount of insulation required to control both heat loss and condensation.

In the case of a flat roof, thermal insulation is usually a rigid board above the deck, or a fibrous quilt directly above the ceiling, depending on the type of roof construction.

There are three recognised designs of a flat roof construction: warm, cold and inverted. Inverted roofs are not very common therefore this type of flat roofs will be not further discussed.

### *2.1.1 Warm roof*

Warm roof structures are most common for flat roofs with no technical level underneath. In a warm roof construction, the thermal insulation is located above the structural layer (roof – slab), resulting in the structural deck and support structure being at a temperature close to that of the interior of the building. It is necessary to incorporate a vapour barrier beneath the insulation in order to prevent moisture vapour being forced into the insulation through thermal pressure from the building. The waterproofing membranes are placed over the insulation to completely encapsulate it.

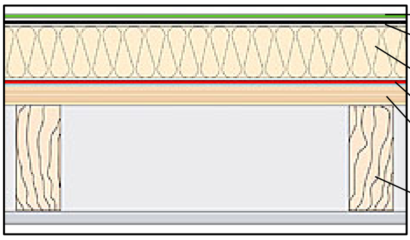



Figure 3: Section through a typical warm roof

### 2.1.2 *Cold roof*

In cold roof construction, the principal thermal insulation layer is located below the structural decking. The concept for this type of design is usually associated with roof constructions having independent ceilings to support the insulation. Adequate ventilation must be provided between the insulation and the underside of the roof deck to prevent the risk of interstitial condensation forming within the construction.
A cold roof design is not generally recommended for new build flat roof applications due to the added requirement for roof void ventilation and the difficulties in preventing heat bridges through the system.

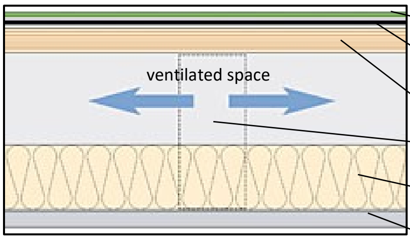



Figure 4: Section through a typical cold roof

## 2.2 Recommended installation practices (warm roof structure)

Non-ventilated warm flat roof structures with a bituminous waterproofing membrane are the most common flat roof structure in the target countries. The most common decks, which will be referred to, are reinforced concrete roof slabs or hollow core slabs either even or laid to falls.

In most cases the thermal refurbishment of a flat roof structure also is a long overdue refurbishment of the waterproofing itself. Leakages have often been repaired insufficiently. The quality of the used waterproofing as well as the design of the connection details to other building elements is poor. Overall, in the outmost cases the existing flat roof structures do not meet the current standards.

There are two options for improving the waterproofing on a current warm roof: 1) Stripping off the failing system or 2) to overlay it. In either case, the first steps are to examine the condition of the deck and supporting structure and the existing waterproofing.

**In case of a thermal refurbishment stripping off the existing flat roof system and applying a new one is mostly the appropriate method.**

State of the Art thermal flat roof structures are light weight constructions and help to ease the roof-slab, which might have been structurally effected by long-term penetration of dampness. Overlaying the current roof is only to be recommended if the existing roof system is generally sound, dry, free from water damage and suitable to take an overlay system (the overlay materials must be compatible with existing materials).
The starting point of any roof refurbishment is a detailed structural survey of the current roof construction.

### *2.2.1 Structural survey*

The structural survey of the existing flat roof shall contain at least following issues:

- Assessment of the roof structure - warm roof, cold roof, inverted roof
  In most cases non-ventilated warm flat roof structures have been installed. They usually contain of following layers listed from top down:
  - Bituminous sealing layer (bituminous roofing felt, asphalt mastic)
  - Cement screed (final surface to apply the bituminous sealing layer)
  - Ceramsite (lightweight expanded clay aggregate) heaping (bonded/not bonded) as thermal insulation layer and sloping screed
  - Bitumen paper as separation layer
  - Roof – slab (even or laid to fall)
- Sloping, and roof-drainage: In many cases the sloping of the flat roof structure is not sufficient. Discolorations of the roof surface, algae growth and standing water are hints of not sufficient sloping. The roof drainage leads either to the inside (rainwater inlets) or to the outside. Special attention shall be paid to the connection of the inlet with the sealing layer
- Roof penetrations: ascertainment of the necessary roof-penetrations such as sewer ventilation, ventilating shafts, structural penetrations for balustrades or other superstructures.
- Visible defects of the sealing layer: ridging, cracks, open joints
- Visible defects of details: insufficient high-rise (skirting), connection to roof penetrations, cover of the roof parapet, etc.
- Rainwater management: Rainwater – sewer (yes/no); tightness of the gravity drainage system (downpipes and the horizontal pipes); material of the downpipes and the horizontal rainwater-sewer
- Examination of the roof slab:
  - From underneath: obvious discolorations, wet stains, flaking of wall paint and/or plaster, mould, etc. are signs for a leaking roof.
  - A long-term penetration of dampness of the roof slab as well as exposed reinforcement steel call for a structural expertise
- Roof diagnostics to detect moisture, which is penetrating into the roof system. There are several methods to detect trapped water such as thermographic imaging and moisture mapping without penetrating the roof. If there is suspicion that the thermal insulation layer is full with moisture the roof sealing layer has to be opened on few spots to examine the exact layering of the roof structure, the moisture content and to gain enough knowledge for qualified suggestion for refurbishment.

- Necessity of equipment which is installed onto the roof such as antennas, ventilation equipment etc.

### *2.2.2 Description of typical refurbishment measures*

Based on the results of the structural survey the appropriate refurbishment measures should be chosen. Most projects require a comprehensive refurbishment comprising of the following measures:

- Removal of the existing flat roof layers down to the structural roof slab
- Installation of a new state of the art flat-roof structure comprising of the following layers (see Figure 5):
  - Ground coat (primer)
  - Vapour barrier
  - Insulation boards glued or mechanically fixed (EPS, XPS, PUR/PIR, mineral wool, …)
  - Waterproofing membrane (bitumen membrane, synthetic membrane, liquid applied systems)
  - Protective membrane (optional, in case of additional layers above the waterproofing)
  - Layer of gravel (or green roof) on top as additional UV- protection and protection against mechanical damages (optional).
- The minimum roof slope shall be 2%.
- Rainwater - inlets (gullies) must be part of the flat roof system structure and must be implemented carefully (see
- Figure 10).
- The gravity drainage systems inside the building shall be renewed. The existing (often cast-iron) downpipes shall be replaced by insulated polypropylene pipes.
- Security-measures for future maintenance work such as single anchor points or a life - line system must be provided.
- After the installation of the new flat roof structures the water impermeability has to be proofed (e.g. by flooding the roof, detection of leakages with electric field vector mapping, etc.). This should be part of the final acceptance.
- The connections of the sealing membrane must be carefully attached to the uprising building such as roof parapet (see Figure 6). The roof edges must be carefully covered with flashing (see Figure 11, Figure 12). All metal flashings and the rain-gutter - system shall be implemented with zinc sheet metal or zinc-coated sheet metal.
- Penetrations of the roof structure should be avoided to the most possible extend. Roof-penetrations which cannot be avoided such as exhaust ventilation shafts, sewage ventilation, cable duct-through with swan-neck, etc. shall be integrated into the new flat roof system with as little heat-bridges as possible.
- Prefabricated concrete slabs placed loose and without any roof penetration on the flat roof-structure (preferable above the central bearing area and according to a structural expertise) shall be used as foundation for necessary technical equipment (outdoor devices of ventilation system, antennas, solar collectors, photovoltaic panels etc.).
- The connection of the flat roof structure to the eaves, roof parapet and to uprising building elements has to be well elaborated.
- Any building work, should be carried out by properly trained and qualified craftsmen.
- The flat roof structure shall be divided into sectors of max 200 $m^2$ (corresponds the max. daily workload). Proper day joints must be formed at the end of each working day to provide a temporary seal. For future maintenance and controlling a lamphole (inspection duct) shall be integrated into the roof structure for every sector.

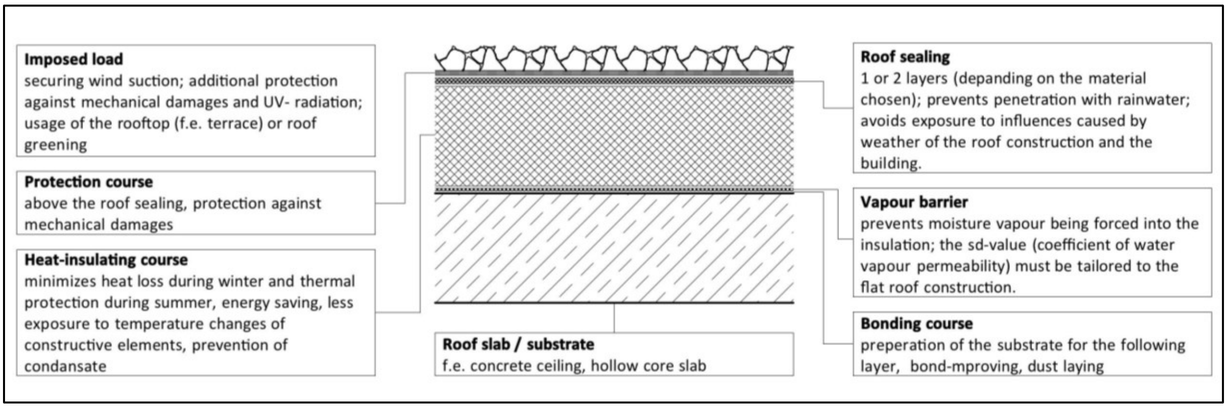


Figure 5: Section through a warm roof construction after a thermal refurbishment

## 2.3 Requirements for materials

Non-ventilated flat roof structures are understood as a "system" and all components must be well matched. The exact layering of the system depends on following aspects:

- The construction of the deck (reinforced concrete roof slab, lightweight deck construction, etc.)
- The loads which should be applied onto the roof (requirements of additional roof loads e.g. ventilation unit)
- Designated use of the roof (walk-able only for maintenance, roof terrace, green roof)
- The chosen waterproofing material (bitumen membrane, synthetic membrane, liquid applied systems)
- Local wind- and snow-loads

Non-ventilated flat roof structures contain following main components:

- Ground coat (primer)
- Vapour barrier
- Insulation boards glued or mechanically fixed (EPS, XPS, PUR/PIR, Rock wool, …)
- Waterproofing membrane (bitumen membrane, synthetic membrane, liquid applied systems)
- Protective membrane (optional, in case of additional layers above the waterproofing e.g. gravel layer)

Only approved and certified (CE-certification) materials shall be used.

### *2.3.1 Vapour barrier*

The vapour barrier beneath the insulation prevents moisture vapour being forced into the insulation through thermal pressure from within the building.

In general the vapour barrier shall have a 6 – times higher tightness than the remaining layers from the inside to the outside. The most important characteristics of the vapour barrier is the sd-value (coefficient of water vapour permeability). The higher the sd-value the less water vapour is transmitted through the building element. A vapour barrier (unlike the vapour retarder) has a sd-value of at least 1.500 m. The most common materials used for vapour barriers are:

- Synthetic membranes (Polyethylene PE – foils)
- Aluminium – foils, also in combination with other materials
- Bituminous seal

Vapour barriers on a bituminous basis are mostly self-adhesive. There are also products on the market, which upper surface has a torch-activated bituminous bonding compound for the adhesion of the insulation. Often the vapour barrier is used as temporary waterproofing. As most of the common bituminous products have an aluminum armour it is important that they are not exposed to UV-rays for a long time due to possible damages. The overlapping of the vapour barrier must be completely bonded or torched; connections to up-rising building elements and joints must be carried out with special care to secure a tight connection (see Figure 6).

### *2.3.2 Thermal Insulation*

The technical design should determine the type and amount of insulation required for the construction by consideration of the factors listed below:

- Required thermal performance (‘U-value’) of the roof (recommended max U-value of the roof construction: 0,2W/K.m$^2$)
- Imposed weight loading to the deck structure.
- Compressive strength required (the ability of the insulation to withstand loads applied directly onto the roof system surface).
- The level and type of traffic that the roof will experience both during and after construction.
- Compatibility with other roofing components.
- Required fire resistance.
- Required acoustic performance.
- Environmental properties.

The most common materials for warm flat roof structures are:

- EPS, rigid expanded polystyrene insulation
- XPS, rigid extruded polystyrene insulation (mainly used in inverted roof design)
- PUR/PIR, rigid urethane foam with or without aluminium foil facing on both sides
- Mineral fibre insulation, rigid mineral wool (rock wool) boards; non-combustible
- Vacuum insulated panels (this insulation panel is specifically designed to provide high thermal performance in areas where height is a limitation)

| Insulation type | Lambda W/(m.K) | Behaviour under fire (EN-13501-1) | Permissible pressure load | Sloped insulation |
|---|---|---|---|---|
| EPS – W25 | 0,36 | Class E (burnable) | 0,03 N/mm$^2$ | yes |
| XPS (CO2) | 0,38 | Class E (burnable) | 0,3 N/mm$^2$ | Unsuitable for warm roof constructions |
| Rock wool | 0,04 | Class A1 (not burnable) | 0,13 N/mm$^2$ | yes |

| | | | | |
|---|---|---|---|---|
| PUR/PIR with aluminium facing | 0,022 | Class E (burnable) | 0,12 N/mm² | no |
| PUR/PIR (flat or tapered) | 0,027 < 80 mm<br>0,026 80 mm - < 120 mm<br>0,025 ≥120 mm | Class E (burnable) | 0,12 N/mm² | yes |
| Celluar Glass | 0,041 | Class A1 (not burnable) | 0,6 N/mm² | yes |

Table 1: Key characteristics of different insulation materials

Comparison of different insulation materials to achieve a U-value of 0,18 W/m².K

| Insulation type | Thickness (mm) | Weight (Kg/m²) |
|---|---|---|
| EPS – W25 | 200 | 5,0 |
| XPS | 200 | 7,0 |
| Rock wool | 200 | 26,0 |
| PUR/PIR with aluminium facing | 120 | 3,6 |
| PUR/PIR (flat or tapered) | 140 | 4,2 |
| Celluar Glass | 210 | 26,3 |

Table 2: Different insulation materials to achieve a U-value of 0,18 W/m².K [1]

For the thermal refurbishment of flat roof structures it is recommended to apply a sloped (tapered) insulation to reduce the applied load and to improve the drainage falls instead of incorporating them into the structure. For the thermal insulation material combined with a bituminous waterproofing membrane a rigid urethane foam (PUR/PIR) is recommended. It is available as tapered (sloped) insulation, it is lightweight and as long as applied according to the manufacturers guidelines usable also with hot bitumen materials.

| Building elements | Recommended max. U-values[2] | Insulation materials, max λ |
|---|---|---|

[1] http://www.bauder.co.uk/technical-centre/flat-roof-design-guide/thermal-insulation; only the insulating course has been considered; EPS has been replenished by the authors

| | | |
|---|---|---|
| | W/(m².K) of the building component | |
| Flat roofs | 0,2 | EPS/XPS/PUR-PIR/Rock wool; λ ≤ 0,04 W/(m.K) |
| Considering typical floor structures such as reinforced concrete slabs the insulation thickness (in average) should be at least 18 cm. | | |

Table 3: Recommended maximal thermal conductivity (U-values) of building elements, insulation materials

### *2.3.3 Waterproofing membrane*

All waterproofing materials and other system components (underlayer, capping sheets) must be part of an approved waterproofing system and shall be supplied by one producer.

In general several materials are available to be used as waterproofing membrane.

- Bitumen membrane: glass-fibre reinforced elastomeric bitumen membranes to be applied in two layers (underlayer, capping sheet); heat-activated and self-adhesive application possible.
- Synthetic membrane: to be applied in one layer: PVC Polyvinyl chloride membrane, FPO Flexible polyolefin membrane; thickness 1,2 – 2,0 mm, mechanically fixed installation or adhered installation possible
- Structural waterproofing: hot melt rubberised bitumen asphalt; used for road- and bridge building
- Cold liquid applied systems: fast curing waterproofing resin, it is applied in 2 coats 'wet-on-wet', with a layer of reinforcement fleece between them; can be used on main roof areas as well as for difficult connection and joint details (to a door sill, rainwater inlet, duct through, etc.) in combination with a bitumen membrane.

The most common water proofing membrane in the target countries of existing buildings is the bituminous water proofing membrane, therefore it is recommended to use such water proofing membrane for the thermal refurbishment of the building.

**Bitumen membrane**[3]

- Underlayer: for the application on top of a PUR/PIR insulation a self-adhesive elastomeric bitumen membrane with a glass fleece reinforcement shall be used; thickness 3mm, minimum technical performance:
  - Tensile strength: length ≥ 1.000 N/50 mm, diagonal ≥ 1.000 N/50 mm
  - Elasticity at fracture of reinforcement: length ≥ 2% diagonal ≥ 2%
  - Cold bending test: -25°C
  - Softening point: +100°C

[2] U-values according to ENEV 2009: German legislation "Energieeinsparverordnung 2009" for refurbishment of buildings (Annex 3, table 1)
[3] EN 13970: 2007 02 01 Flexible sheets for waterproofing - Bitumen water vapour control layers - Definitions and characteristics

- Capping sheet: torch applied, heavy duty elastomeric bitumen membrane with excellent low temperature flexibility as well as very good weathering and ageing resistance characteristics shall be used. For exposed application a membrane with a mineral finish, for green roof applications a root resistant torch-applied membrane must be used. Thickness 5 mm prefered technical performance:
  - Tensile strength: ≥ 1.000 N/50 mm
  - Elasticity at fracture of reinforcement: ≥ 45%
  - Cold bending test: -36°
  - Softening point: +120°C

For fire safety reasons (see local standards and regulations) an additional gravel layer on top of the bitumen membrane might be necessary. To avoid mechanical damages to the waterproofing membrane and to give additional UV-protection we recommend applying a protective membrane (recycling rubber granulate material) and a gravel layer anyway.

## 2.4 Selected construction details

### *2.4.1 Connection of the flat roof construction to rising building elements (wall, roof parapet, etc.)*

- A roof slope ≥ 5° requires at least 15 cm height of the connection above the surface of the roof cover. Roof slopes bigger than 5° require at least 10 cm. In areas rich in snow the height of the connection shall be increased.[4] It is recommended carrying out a connection height of 30 cm in general.
- The joining membrane (to the roof membrane) shall be mechanically fixed at the upper edge region to secure a slipping of the membrane e.g. with a pinching rail (see Figure 6).
- The infiltration of moisture behind the roof membrane must be prevented by implementing a watertight connection using e.g. profiles, which are sheltered from rain or a water proofed wall covering (see Figure 6)
- A wedge (e.g. of insulation material) shall be used when connecting the roof with rising building elements with a 2-layer bituminous roof-membrane (see Figure 6).

[4] Minimum requirement according to the German „Flachdachrichtlinie" (guideline of flat roof constructiions)

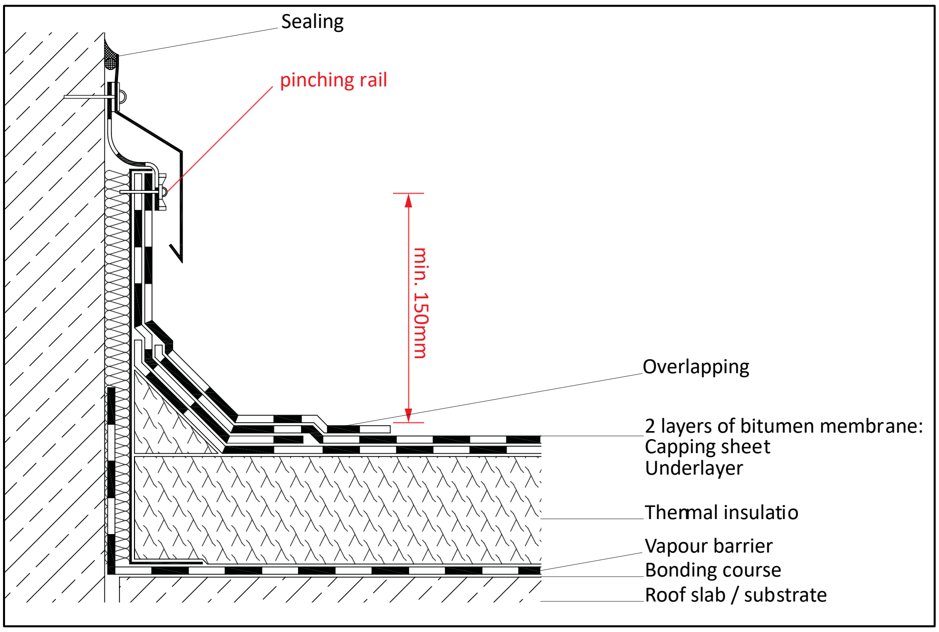



Figure 6: Connection of the flat roof construction to rising building elements[5]

### 2.4.2 *Connection to roof penetrations*

Chimneys, ventilation shafts and pipes, curbs for light cupolas, columns, masts, anchorages, etc. count among roof penetrations. In general roof penetrations should be avoided to the maximum possible extend as they are weak points of the water proofing layer. A number of single roof penetrations shall be combined to a bigger one. Following important details shall be considered in the design works:

- Roof penetrations are to be treated as connections. They can be implemented either with an adhesive flange, a preformed gasket, a clipped connection, or with a liquid applied waterproofing system.
- The distance between roof penetrations to other building elements such as connection to a rising wall, movement joints or the roof edge shall be min. 300 mm (preferable 500 mm). This provides the preparation of a workmanlike and durable connection. The outer boundary of the flange is determinative.
- The connecting flange of a single pipe penetration shall be raised up from the water-carrying layer.

[5] Source: originally from the brochure “Flachdach-Systeme” by Bauder (http://www.bauder.at/fileadmin/bauder.at/daten/downloads/Flachdach/FD_Prospekte/Details/Bauder_Detailkonstruktionen_Bitumen_Prospekt_0513_AT.pdf)

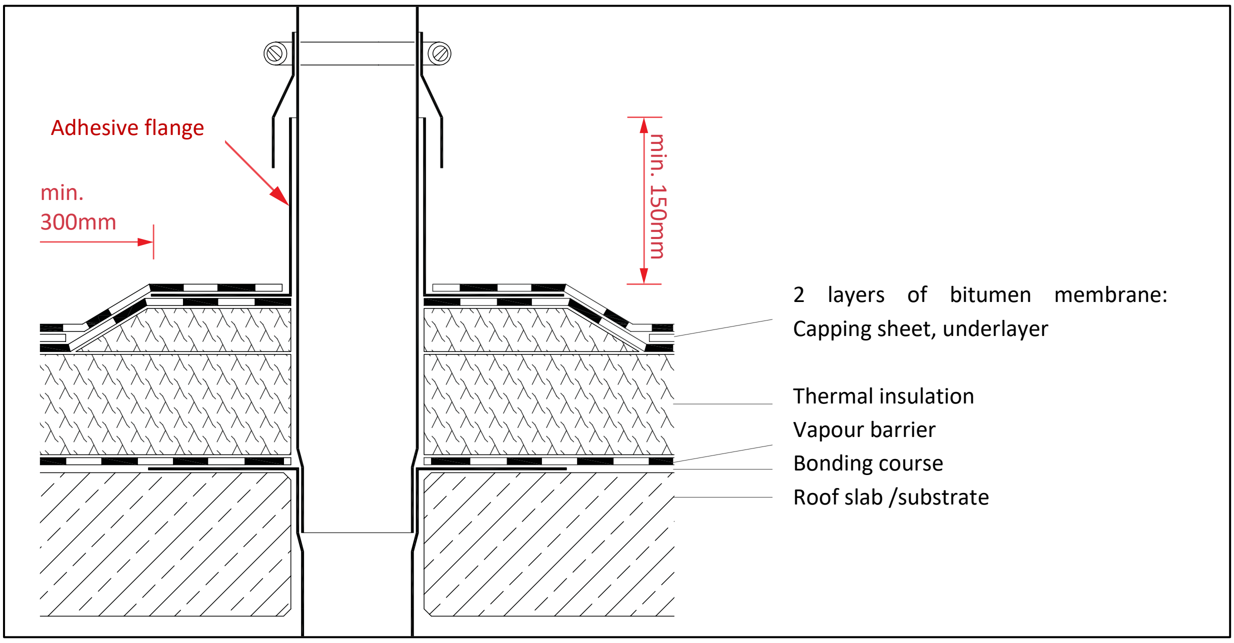



Figure 7: Connection to roof penetration with an adhesive flange

### *2.4.3 Connection to doors*

- The height of the connection shall be min. 150 mm above the surface of the roof cover (gravel layer, pavement). This shall prevent water intruding above the threshold into the building by harsh weather conditions (heavy rain, snowfall, etc.)
- A reduction of the height to 50 mm is possible, when a water retention system for terraces / roofs is implemented (e.g. drainage channels with a grating cover).
- Barrier-free connections are special constructions and need coordination between the architect and the execution as well as additional measurements.

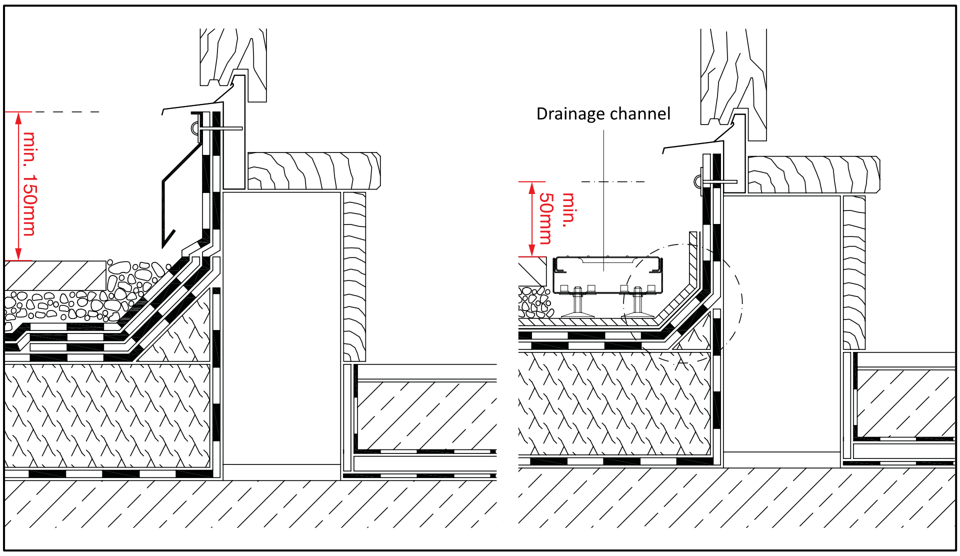



Figure 8: Connection to doors, schematic drawing

### 2.4.4 Movement joints

- Movement joints shall be raised up from the water-carrying layer and shall be implemented as high-point of the roof area (e.g. by introducing a wedge made of insulation material or an up-stand).
- Areas of a roof, which are separated by movement joints shall be dewatered independently.
- The vapour-barrier shall also incorporate the movement joints.

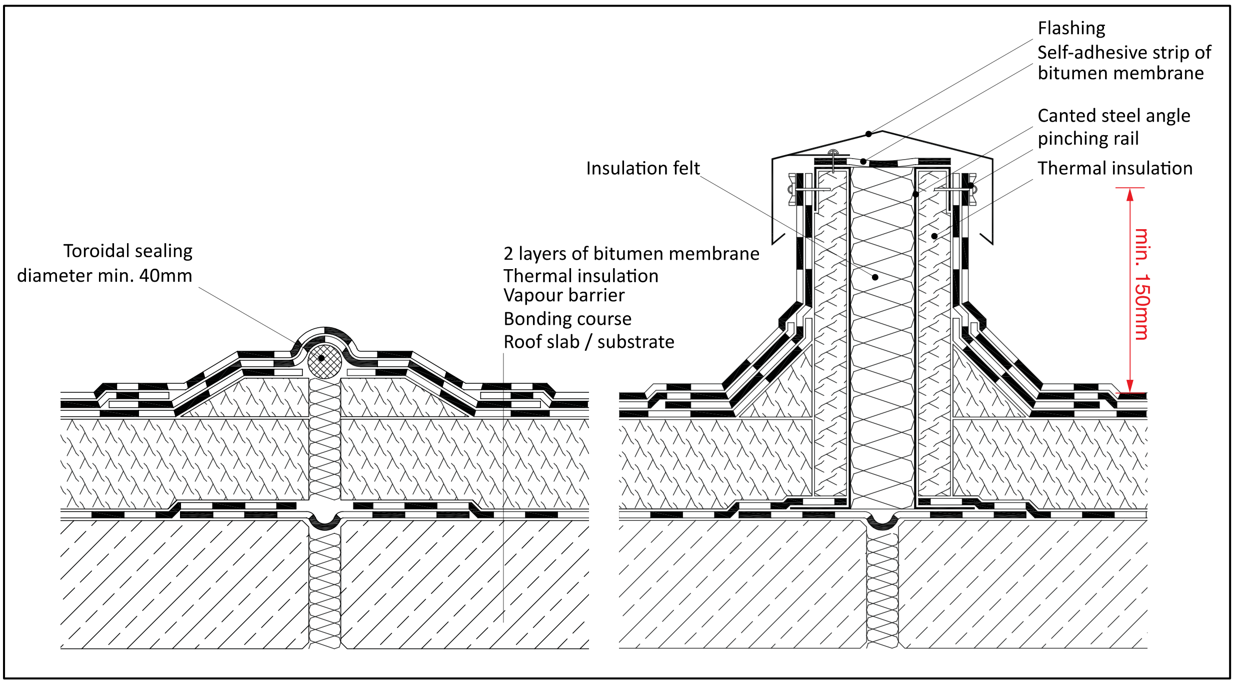



Figure 9: Movement joints: implementation with a wedge and an up-stand (for bigger movements)

### 2.4.5 Roof drainage

- Flat roofs with roof drainage to the inside must have at least two outlets or one outlet and a security-outlet (e.g. water-sprout). The outlets must be at the lowest point of the roof-area.
- The roof outlets have to be fixed to the substructure of the roof. For insulated roof structures with a vapour barrier a two-part roof outlet consisting shall be used in order to connect the vapour barrier and the waterproofing membrane. If there are any heated rooms below only heat-insulated roof outlets shall be used.
- For service reasons the roof outlets must be freely accessible: For terrace areas a removable grating shall be installed above the outlet; the independently moving terrace cover must be guaranteed towards the outlet to avoid damages. In case of rooftop greening or gravel covering the outlet shall be spared.

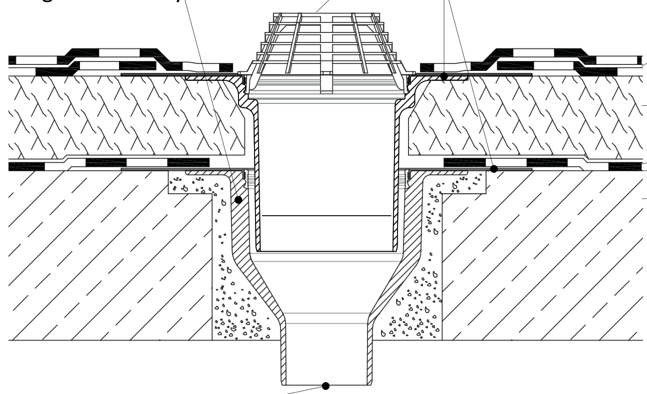



Figure 10: Schematic drawing of a two-part roof outlet for a heat insulated roof with vapour barrier and a conventional gravity drainage systems

### 2.4.6 *Structural design of the eaves*

- In case of water drainage to the outside with hanging gutters an eave flashing shall be implemented as joint to the roof membrane.
- Wooden edge boards or a heat insulated metal profiles can be used to fix the eave flashing. They must be 10 mm lower than the Insulation-layer.
- Gutter brackets shall be flush with the edge board.

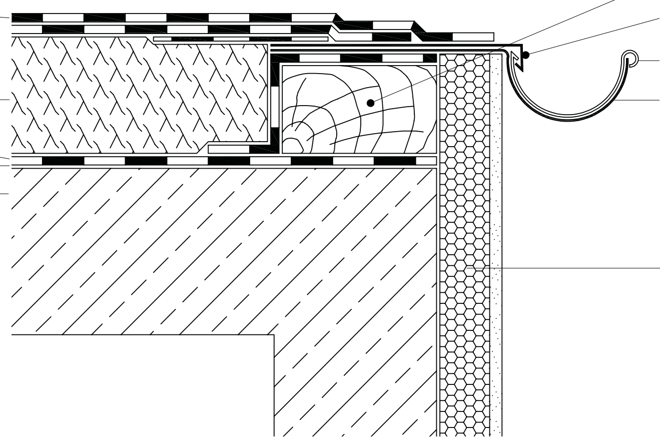
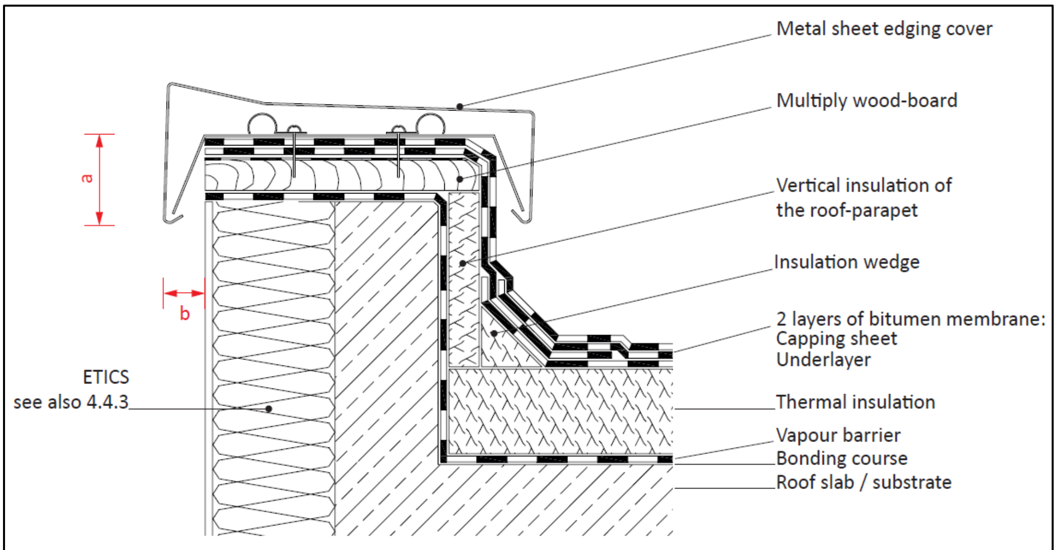



Figure 11: Schematic drawing of an eave construction with a wooden edge board and a hanging gutter

### 2.4.7 Roof edge

- At the edges of a roof sealing it is necessary to introduce an edging board or a roof-parapet (except water drainage to the outside with hanging gutters).
- Either edge profiles (single-piece or multi-piece profiles) or a roof parapet with a metal sheet cover shall be implemented.
- The min. height of the roof edge shall be 10 cm above the roof surface (gravel, pavement, etc.) with a max. roof-slope of 5°. A roof slope with more than 5° reduces the height of the roof edge to a minimum of 5 cm.
- The exterior flange of edging boards or covers shall overlap the upper edge of the render or the façade surfacing by at least:
    - 5 cm for up to 8 m building height
    - 8 cm for 8 – 20 m building height
    - 10 cm for more than 20 m building height
- The overhang of the edging board or cover must have water drip with a distance of at least 2 cm to building elements, which shall be protected.
- The construction of the roof edge must withstand wind loads. The local wind load values must be used for the detailed design of the roof edge.
- The cover of a roof-parapet shall always dewater to the roof side (min. 5°)




| Building height | < 8 m | < 20 m | > 20 m |
|---|---|---|---|
| Minimum overlap a in mm | ≥ 50 | ≥ 80 | ≥ 100 |
| Minimum distance b in mm | 20 | 30 | 40 |

Figure 12: Schematic drawing of a roof parapet with a metal sheet cover dewatering to the roof side. The overlap (a) and (b) depends on the building height

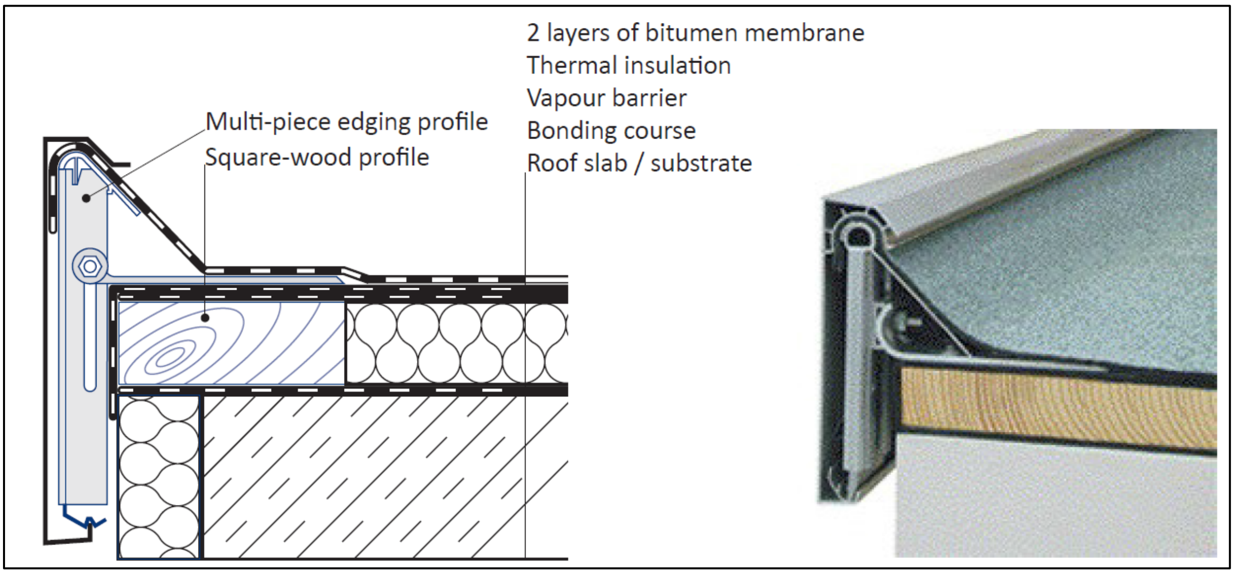



Figure 13: Schematic drawing of a multi-piece edging board profile[6]

# 3 Thermal Insulation of cold roof structures

## 3.1 Typical refurbishment measures for cold roofs & top floors

The application of a thermal insulation at the ceiling line of the roof slab or a non-heated technical level provides an economic solution for improving the energy performance of the building. In the event mineral-wool is used as insulation material, not only the thermal efficiency of the building's roof will be improved but – as additional benefit – delivers enhanced fire protection and sound absorption. The installation of a walk-able surface (e.g. OSB[7] – boards, screed) on top of the insulation will ensure the assess ability of maintenance works.

For pitched roof constructions the following important issues have to be regarded:

- The roof construction must be watertight and in a good technical condition.
- If a metal cladding is used either a sub-roof membrane or an anti-condensate coating on the side exposed to the attic must be applied to prevent moisture caused by condensate penetrating the insulation.
- The roof framework must fulfil the structural needs – a structural expertise beforehand is recommended.
- Birds and other animals shall not have access to the attic.
- National fire protection requirements.

In a lot of slab blocks of the Soviet period a technical level has been installed above the last used level and beneath the (flat-) roof construction. Technical levels are in general non-heated spaces. If the

[6] Source: http://polybit.de/downloads/broschueren/Classic.pdf
[7] Oriented strand board

technical level is in use for service equipment a durable, dust-free and loadable floor construction above the insulation shall be installed (e.g. floating cement screed with an applied screed sealing).

For the insulation of the technical level the following important issues have to be regarded:

- Load bearing capacity of the slab: often there is already an insulating heaping with a cement screed above installed (e.g. “ceramsite” – a lightweight expanded clay aggregate). Applying additional insulation and a floating screed above will cause additional load. A structural expertise will be necessary beforehand or the existing floor construction must be demolished.
- To provide heat-bridges at the connection uprising walls and ceiling the walls shall be insulated to a height of minimum 1 meter above floor-level.
- A possibility to naturally ventilate the technical level must be provided.
- The actual roof must be watertight and in a good technical condition.
- National fire protection regulations.

## 3.2 Requirements for materials

### *3.2.1 Insulation of the roof slab in case of a non-habitable loft /attic of pitched roofs*

The most common insulation material used is mineral wool[8], either rock- or glass- wool, boards or felt. The main requirements are:

- Diffusion open
- Incombustible
- Resistant to moisture
- Compression resistant (provides a walk-able and load distributing cover)

The thickness of the load distributing cover has to be chosen according to following requirements:

- Occasionally access (e.g. OSB-board[9] ≥ 15 mm, chipboard ≥ 16 mm; the cover than will be applied only at areas, which shall be walk-able due to maintenance reasons)
- Utilization as storage-area: (e.g. OSB-bord ≥ 18 mm, chipboard ≥ 19 mm)[10]

There are also composite elements on the market, which combine a loadable mineral-wool insulation with a bonded gypsum-fiber board (thickness 10 mm). The cover is suitable for maintenance and can be reinforced with a 2nd layer of gypsum-fiber boards for a more loadable utilization.[11]

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[8] See: EN 13162:2015 03 15, thermal insulation products for buildings - factory made mineral wool (MW) products - specification
[9] See: EN 300:2006 09 01, Oriented Strand Boards (OSB) - Definitions, classification and specifications
[10] The stated material thickness depends on the density of the insulation material. Reference product: mineral-wool insulation board Rockwool®, Tegarock®L
[11] Reference product: Isover Saint-Gobain, DBL-C

| Building elements | Recommended max. U-values[12] W/(m².K) of the building component | Insulation materials, max λ |
|---|---|---|
| Pitched roofs | 0,2 | Rock wool; λ ≤ 0,04 W/(m.K) |
| Considering typical floor structures such as reinforced concrete slabs the insulation thickness should be at least 18 cm. | | |

Table 4: Recommended maximal thermal conductivity (U-values) of building elements, insulation materials

### *3.2.2 Insulation of the floor of technical levels*

Beside of mineral-wool insulations (like described before) also EPS insulation boards[13] can be used when covered with floating cement screed. This allows higher loads to be applied. It is important that the surface of the substrate (slab) onto which the insulation boards are applied is even (e.g. by installing a sand leveling) to guarantee a homogeneous load distribution. The cement screed will be the fire-protection for the EPS-boards. The main requirements for the insulation material are:

- Water-repellent
- Compression resistant (according to the imposed loads - cement screed, equipment, etc.)

| Building elements | Recommended max. U-values[14] W/(m².K) of the building component | Insulation materials, max λ |
|---|---|---|
| Technical level | 0,2 | Rock wool/EPS; λ ≤ 0,04 W/(m.K) |
| Considering typical floor structures such as reinforced concrete slabs the insulation thickness should be at least 18 cm. | | |

Table 5: Recommended maximal thermal conductivity (U-values) of building elements, insulation materials

[12] U-values according to ENEV 2009: German legislation "Energieeinsparverordnung 2009" for refurbishment of buildings (Annex 3, table 1)
[13] See: EN 13163:2015 04 01, Thermal insulation products for buildings - Factory made expanded polystyrene (EPS) products - Specification
[14] U-values according to ENEV 2009: German legislation "Energieeinsparverordnung 2009" for refurbishment of buildings (Annex 3, table 1)

## 3.3 Recommended installation practices

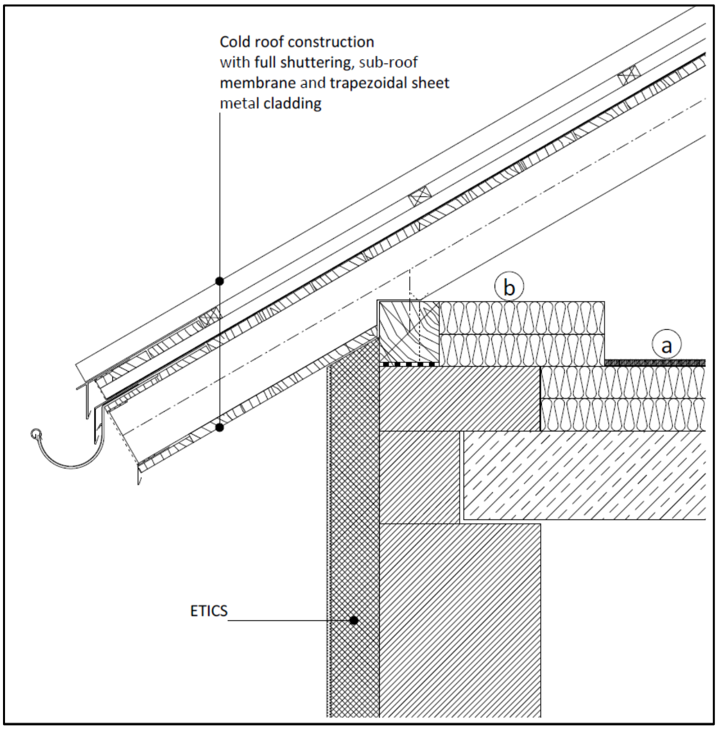


Figure 14[15] Thermal insulation of a concrete roof slab of a pitched roof

Detail (a): If the topmost suspended floor is of reinforced concrete, a vapour barrier and airtight membrane are not required. It is recommended to apply the insulation in 2 layers (e.g. 2 x 10 cm rock wool or EPS boards → total insulation 20 cm). Firstly, the boards are easier to handle and fit; secondly, the joints between the boards can be staggered to minimize convection in the joints. Flooring-grade boards with glued joints on top of the insulation will provide a walk-able surface.

Detail (b): The top of the masonry is covered insulation material in order to minimize the geometrical thermal bridge effect at the top corner of the room.

[15] Figure 12 is taken from: „Energy-Efficiency upgrades, Principles, Details, Examples“, Edition Detail, Birkhäuser, 2007; page 31

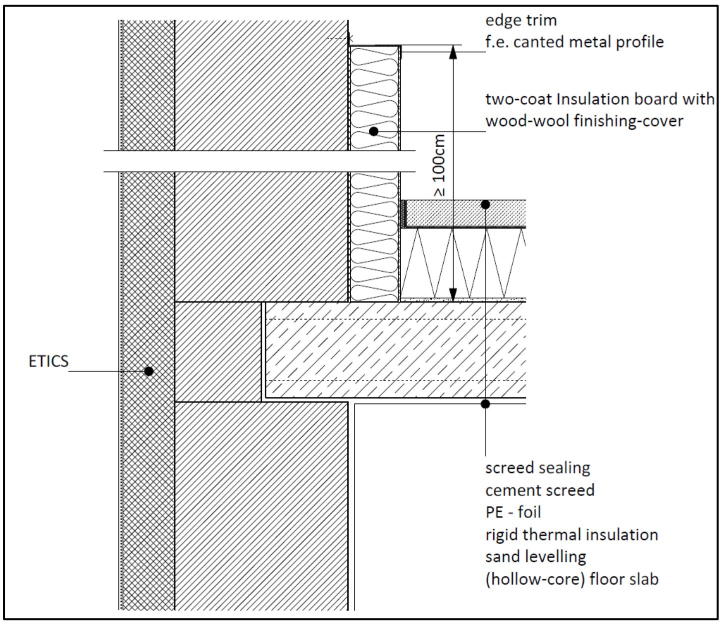


Figure 15[16] Thermal insulation of a non-heated technical level

# 4 Refurbishment of exterior walls

## 4.1 Typical refurbishment measures for external walls

The following measures usually need to be considered when implementing a comprehensive thermal refurbishment of the external walls. The measures are subject to variation according to the actual needs of the individual project.

- Removal of all kind of equipment that is mounted onto external walls such as metal service staircase and ladders, air conditioning units, pipes, electric equipment, etc.
- Demolition of all building elements, which jut out the façade like cantilevered porch roofs, etc. and elements which are not of any structural importance. The evenness of the façade allows a simpler installation. Ornaments can be replicated with special heat-insulation profiles.
- The substrate onto which external thermal composite insulation system (ETICS) is to be applied must be checked and prepared carefully.
- Applying an ETICS to all exterior walls. The thickness of the thermal insulation material depends on: U-value to be achieved and the material properties of the insulation material.
- Replacement of the existing sidewalk around the building, excavation of the soil approx. 1 m below ground level around the building shell in order to install a rigid hydrophobic insulation.

[16] Figure 12 is taken from: „Energy-Efficiency upgrades, Principles, Details, Examples“, Edition Detail, Birkhäuser, 2007; page 31

- Insulation of the plinth approx. 0.8 m below ground level with extruded polystyrene boards (XPS) and an additional protective and drainage layer. If the building has a heated basement, the hydrophobic insulation and the thermal insulation shall be applied until the foundation.
- Backfilling and installing of a new concrete sidewalk around the buildings.
- All porch-roof structures, which have been demolished or removed, shall be renewed by new structures with as little heat-bridges as possible. Especially the connection to the ETICS has to be implemented carefully considering primarily the splashing water.
- Heat bridge - free reinstallation of pipes, lightning conductors and equipment (e.g. air conditioning units) onto exterior walls

## 4.2 Requirements for materials

All components of the ETICS, which are applied onto an exterior wall must be part of an approved and certified system according to EOTA (European Organization for Technical Approvals). To following international guidelines and standards shall be referred to[17]:

- **ETAG 004** Guideline for European technical approval for external thermal insulation composite systems with rendering
- **ETAG 014** Guideline for European technical approval for plastic anchors for thermal insulation composite systems
- **EN 13162** Thermal insulation materials for buildings – factory-made mineral wool (MW) products - specification
- **EN 13163** Thermal insulation materials for buildings – factory-made expanded polystyrene (EPS) products – specification

The insulation of standard exterior walls consists of the following main components:

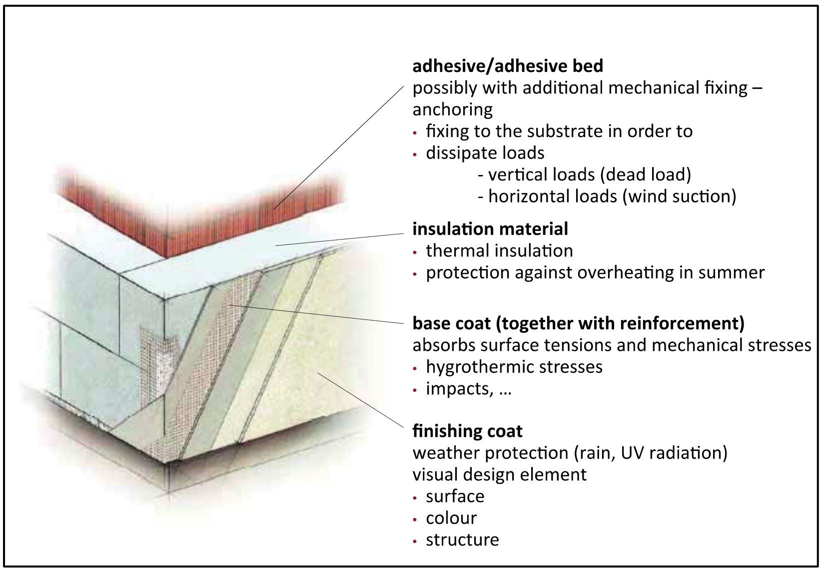


Figure 16: Components of the ETICS[18]

[17] The named guidelines primarily deal with insulation materials of the EPS and MW product types

Basically, ETICS consist of the components defined in the following.

### 4.2.1 Fixing

From the technical design point of view, ETICS are differentiated according to the methods of fixing:

- Bonded system:
  - Purely bonded systems.
  - Bonded systems with supplementary mechanical fixings. The load is totally distributed by the bonding layer. The mechanical fixings are used as a temporary connection until the adhesive has dried.
- Mechanically fixed system:
  - Mechanically fixed systems with supplementary adhesive. The load is totally distributed by the mechanical fixings. The adhesive is used primarily to ensure the flatness of the installed system.
  - Purely mechanically fixed systems.

It is recommended to use a mechanically fixed systems (anchors).

### 4.2.2 Insulation material

The most commonly used insulation materials at present are expanded polystyrene (EPS)[19]
and mineral wool (MW)[20].
Extruded polystyrene (XPS)[21] is used in areas exposed to splashing water (e.g. plinth area[22]).
National requirements such as fire safety, noise protection, wind-loads, etc. must be considered.

| Building elements | Recommended max. U-values[23] W/(m².K) of the building component | Insulation materials, max λ |
|---|---|---|
| External walls (façade insulation) | 0,24 | EPS or Mineral wool; λ < 0,04 W/(m.K) |
| Base perimeter insulation (plinth) | 0,24 | XPS; λ < 0,04 W/(m.K) |
| Considering typical wall structures such as limestone or prefabricated concrete slabs the insulation thickness should be at least 12 cm. | | |

Table 6: Thermal conductivity (U-values) of building elements, insulation materials

### 4.2.3 Render system

This consists of the reinforced base coat (= base coat with reinforcement embedded in it), the system

[18] The illustration is taken from the European Guideline for the application of ETICS; published by the European Association for insulation composite systems; 2011; page 14.
[19] in accordance with EN 13163
[20] in accordance with EN 13162
[21] in accordance with EN 13164
[22] Plinth area is the wall surface ca. 50 cm above the ground surface level
[23] U-values according to ENEV 2009: German legislation "Energieeinsparverordnung 2009" for refurbishment of buildings (Annex 3, table 1)

primer, the finishing coat and system-compatible paint coatings.

The coating of the insulation boards should enable the diffusion of moisture to the outside air. A mineral composition of the render is to be preferred. The application of ETICS will serve as a “new skin” for the building; it will improve the energy balance of the building as well as it is used to renovate the defective fabric of the existing building (building maintenance).

## 4.3 Installation practices

The **European Guidelines for the Application of ETICS**[24] in the latest version are the recommended standard for the final design and installation of the external thermal insulation composite system.

Following aspects must be paid particular attention:

### *4.3.1 National building law requirements*

In supplementation of European standards[25] , the respective nationally-specific building law must ensure the implementation of essential requirements, which apply to the construction works as a whole and the individual works (ETICS) and govern the following areas:

- Mechanical resistance and stability
- Safety in case of fire
- Hygiene, health and the environment
- Safety in use
- Protection against noise
- Energy economy and heat retention

### *4.3.2 System structure (components, materials)*

Only as a system approved and certified ETICS can be used. This obliges all involved in the construction work to adhere absolutely to the system. The individual components of the system are described in the relevant ETA (chapter 4.2). If this obligation is breached, the ETICS loses its approval under building law. This also has significant effects on any existing guarantee claims.

### *4.3.3 Substrate – testing and preparation*

In case of old buildings and/or existing rendered substrates, the checking of the substrate onto which the ETICS is to be applied, as well as preparation of the substrate is of utmost importance[26]. On these substrates, all types of ETICS must be bonded and in addition mechanically fixed.

### *4.3.4 Prevention of errors*

The European Guidelines for the Application of ETICS recommend a checklist[27] to be used for the preparation of the construction site and the associated working steps. Questions to all crucial steps

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[24] Published by: EAE European Association for External thermal insulation composite systems, 2011. The guideline is available under http://www.ea-etics.eu/

[25] The European Construction Products Directive (CPD)

[26] Valid methods of testing the substrate for its suitability for the application of ETICS and the pre-treatments of the substrate, which may be necessary are described in section Substrate – testing and preparation, chapter 7, page 19 to 25 of the European Guidelines for the Application of ETICS.

from the survey of the existing situation, the design and the application are to be answered. Each list should be worked through before carrying out the working steps. It shall be also basis for the monitoring and site supervision.

### *4.3.5 Application of the System*[28]

The application of the system structure consists of the following main working steps:

- Mixing and applying the adhesive mortar
- Laying of the insulation panels
- Anchoring the insulation panels
- Application of the base coat with reinforcement
- Application of the finishing coat

The application must follow the European Guidelines for the Application of ETICS and the manufacturer's instructions.

### *4.3.6 Design details (drawings)*[29]

The exemplary details shown in the European Guidelines for the Application of ETICS are the recommended standard for the application works.

## 4.4 Construction details

The following exemplary details are a short extract of the details shown in the European Guidelines for the Application of ETICS and should illustrate the design in principle. Further construction details can be found in Annex II of the European Guidelines for the Application of ETICS.

[27] Chapter 8 of the European Guidelines for the Application of ETICS
[28] Chapter 10 of the European Guidelines for the Application of ETICS
[29] Chapter 11; annex II, page 61 et seq of the European Guidelines for the Application of ETICS

### 4.4.1 *Recessed base without existing perimeter insulation*[30]

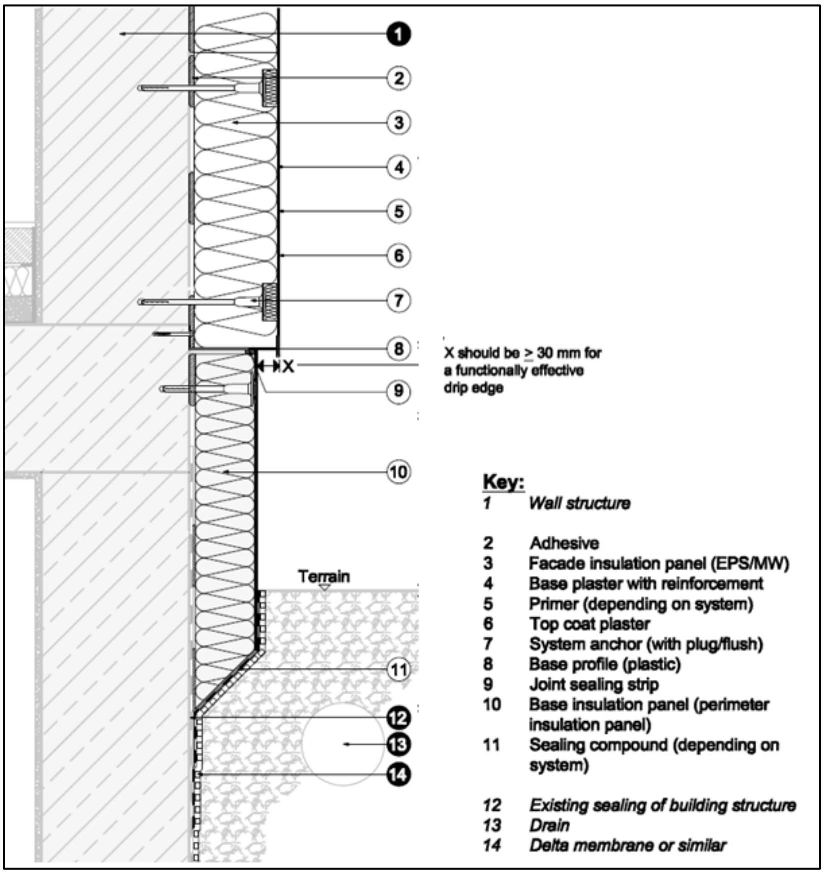



Figure 17: Recessed base without existing perimeter insulation

[30] European Guidelines for the Application of ETICS, annex 2detail drawings, page 63

### 4.4.2 Roof connection to back-ventilated cold roof[31]

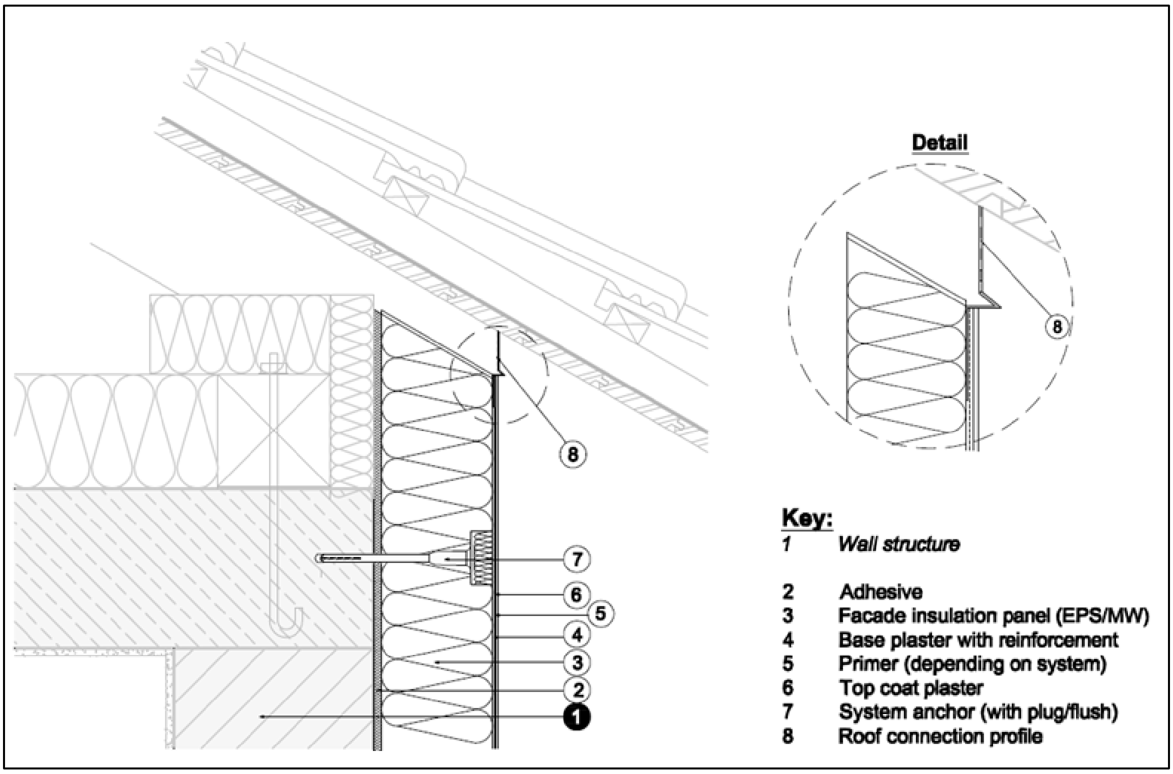



Figure 18: Roof connection to back-ventilated cold roof

[31] European Guidelines for the Application of ETICS, annex 2detail drawings, page 85

### 4.4.3 Roof parapet[32]

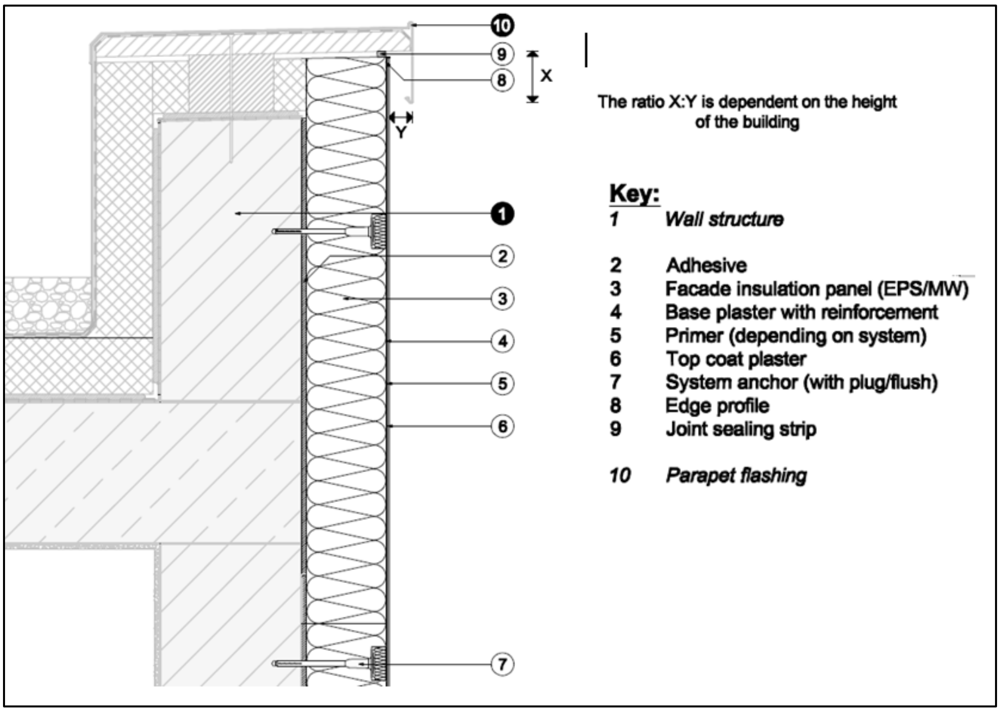



Figure 19: Roof parapet

[32] European Guidelines for the Application of ETICS, annex 2detail drawings, page 87

# 5 Refurbishment of external windows and doors

## 5.1 Typical refurbishment measures for windows & doors

In the course of a thermal refurbishment of a building shell transparent building elements such as windows and doors are crucial elements, which – in most cases – will be renewed by elements with an optimized frame system and glazing. To optimize the performance it is important to well coordinate the different functions of the new elements such as:

- Daylight
- Natural ventilation
- Heat protection during summer (e.g. by installing solar protection devices)
- Cold protection and heat gain during winter

The individual refurbishment measures depend on the installation of new windows or refurbishment of existing windows which are outlined in the chapters below.

The windows and doors shall match the local legislation and norms concerning matters of security (emergency escape, risk of falling and falling through), accessibility for handicap people, etc. Special legal requirements for schools, hospitals, etc. must be considered.

## 5.2 Requirements for materials

Windows and doors are multifunctional building elements, which fulfill a lot of properties according to their object related requirements. A summary of the performance spectrum of windows and outside doors gives the European product standard EN 14351-1. A correct installation of those building elements and their connection to the building shell are crucial influencing factors for their functionality and their durability.

To identify the requirements it is necessary to know about the impacts a window is exposed to as built into an external wall.

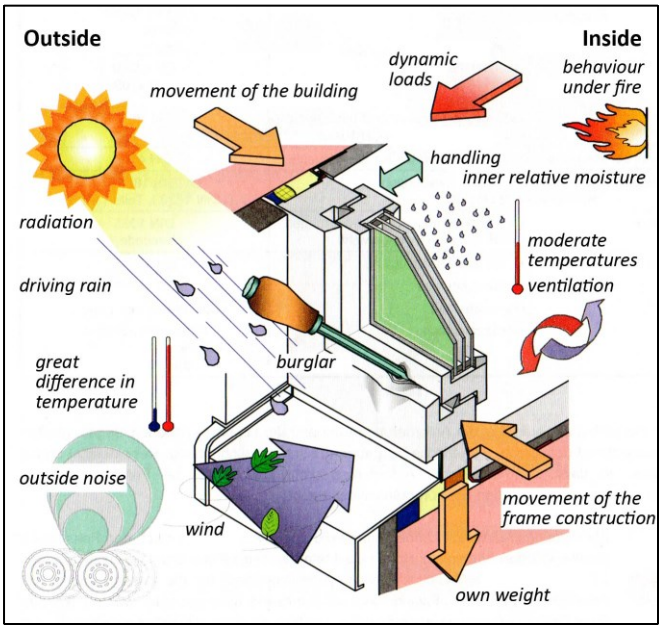



Figure 20: Scheme of the various impacts on a window and its connections[33]

The most common frame materials for windows and outside doors are: wood, wood – aluminum (wooden frame with an external aluminum covering layer for a better weather protection), aluminum (thermal isolated) and synthetic materials (PVC).

PVC-frames are the most common and easy available in the target countries. One of the reasons is – compared to the other materials – the attractive price. The recommended standard for windows and external doors shall be[34]:

- PVC frames: unplasticises polyvinylchloride (PVC-U) profiles shall be used (according to EN 1627)
- Frame-profiles with at least 5 chambers and an overall depth of 70 mm.
- The minimum overall depth of reinforcement profiles inserted into the reinforcement chamber shall be 35 mm; only insolated reinforcement profile shall be used
- All windows/doors should have a CE mark.
- For insulating glass according to ETAG 002 (Structural Sealant Glazing Systems) and to EN 1279-(1-6)
- All sealant tapes (adhesive or non-adhesive), sealing materials and expanding foams used must have a European building approval[35].

| Parameter | Min criteria | Relevant standard | Comments |
|---|---|---|---|
| Water tightness | 9A | EN 12208 | |
| Air permeability | Class 4 | EN 12207 | |

[33] RAL – Gütergemeinschaft Fenster und Haustüren, Leitfaden zur Montage: 2014-03; Page 7
[34] As reference product for PVC window and door profiles Rehau Euro-Design 70 plus is used. (http://www.rehau.com/de-de/bau/fenster-fassadensysteme/fenstersysteme/fenster-euro-design-70)
[35] EOTA (European Organisation for Technical Approvals)

| | | | |
|---|---|---|---|
| Thermal conductivity (U-value) of windows | Uw < 1,3 W/(m².K) or better | EN ISO 10077-1 2006 | Calculation according to EN ISO 10077-1 2006 based on individual values for frame, glass and spacer |
| Solar transmittance | g value < 0,6 or better | EN 410 | |
| Noise protection | $R_{w,P}$ > 42 dB | EN ISO 717-1 | |
| Burglar resistance | WK1 or better | EN V 1627 | |

Table 7: Minimum criteria's for windows

| Parameter | Min criteria | Relevant standard | Comments |
|---|---|---|---|
| Water tightness | 9A | EN 12208 | |
| Air permeability | Class 4 | EN 12207 | |
| Thermal conductivity (U-value) of exterior doors | Uw < 1,8 W/(m².K) or better | EN ISO 10077-1 2006 | Calculation according to EN ISO 10077-1 2006 based on individual values for frame, glass and spacer |
| Solar transmittance | g value < 0,6 or better | EN 410 | |
| Noise protection | $R_{w,P}$ > 42 dB | EN ISO 717-1 | |
| Burglar resistance | WK2 or better | EN V 1627 | |
| Mechanical durability | Class 3 | EN 12400, EN 1191 | Only for main exterior doors |

Table 8: Minimum criteria's for exterior doors

## 5.3 Recommended installation practices

### *5.3.1 Installation practices for new windows and doors*

A technical correct connection of window and door elements to the building shell including the construction itself, the geometry of joints, the fastening, the thermal insulation and sealing is crucial and must be designed carefully together with other measurements of a thermal refurbishment of the building shell such as an external thermal insulation composite system. For a better understanding of the principals of the implementation of the connection see the following layer-model.

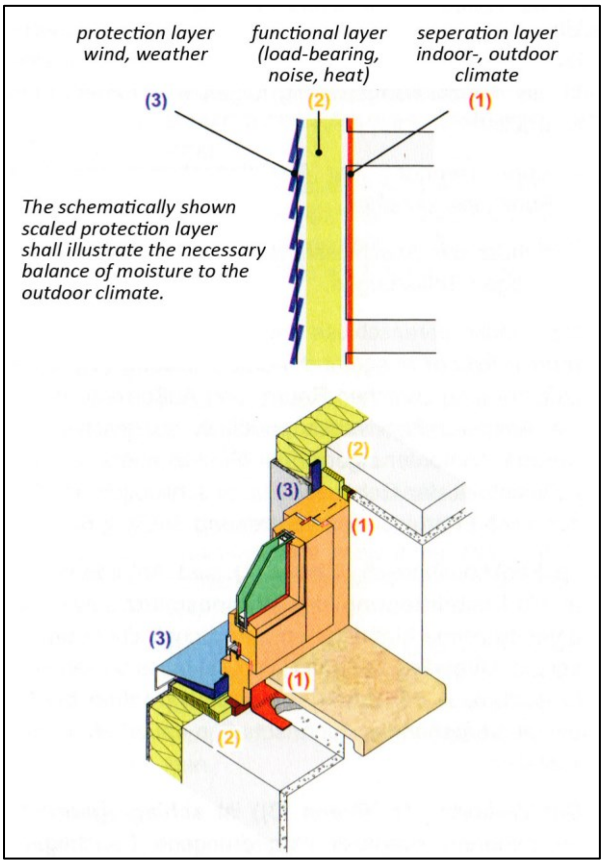



Figure 21: General layer-model of a building shell and its transcription to the connection joint of a window.

Layer (1) – separation layer (indoor plaster, indoor window sill, etc.)

The connection to the building shell must be airtight all around on the inside.

*Layer (2) – functional layer (wall structure incl. heat insulation, window, etc.)*
It meets the requirements of load bearing, thermal protection and noise protection. Layers (1) and (3) **must secure that the functional layer stays dry** in order to durably ensure the previously named functions.

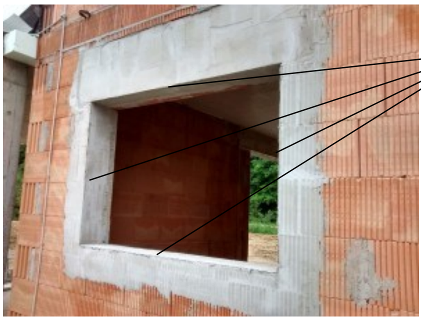
*Layer (3) – protection layer (outside plaster, outside window sill, etc.)*
It must be resistant to heavy rain; moisture, which eventually has been penetrated, must be conducted to the outside in a controlled manner. To avoid damages due to moisture the building element/joint/wall must be understood as a system. The principle “tighter to the inside than to the outside” must be applied to this system.

The **German Quality marks “RAL”** for the final design and installation of windows and doors should be the standard for the implementation of windows and doors.

The connection joint of the window/door and the building shell must meet the requirements of stability, thermal protection, moisture proofing and sound insulation. The minimum distance between the window/door case and the wall opening must be at least 10 mm, the max distance shall not more than 20 mm.

Before the installation of the windows and doors, the reveals must be carefully prepared for the installation in the following way:

- Removing of all loosen parts of the walls
- Apply a trowel-finished layer (smooth finish) to the existing reveal of walls by using e.g. a reinforcing coat mortar (as it is used for ETICS) see Figure 22. The surface of the wall opening must be smoothed (as accurately as possible) and fair faced in order to allow a state of the art sealing.



Trowel finished layer on the window reveal

Figure 22: Properly prepared windows reveals prior to the installation of the window

Outside sealing membrane glued properly to the trowel layer

Figure 23: Outside sealing membrane glued to the trowel layer

- The fixing of the window/door element must take into account the transmitted loads, the strength of the surrounding structural elements and the movements in the connection joint (expanding foam cannot be used as only means of fastening). Since the window-frames shall be installed plain with the outside of the exterior wall a cleated joint shall be considered instead of the standard fixing with wall screws (danger of chipping of parts of the wall due to small distance to the outside)

The state of the art installation of windows and doors provides an implementation of the connection joint in three layers (implementation of windows according to RAL quality marks[36]):

- Inner sealing layer (diffusion-tight)
- Heat insulating layer
- Outer sealing layer (diffusion-open, resistant to heavy rain)

The new windows can be installed in general in 2 different positions:

1) Installation of the window within the external wall see Figure 36 and

2) Installation of the window flush with the exterior wall see Figure 34.

[36] The RAL quality marks are a German technical standard released by the German Institute for Quality Assurance and Certification. The German Norm DIN 4108 Teil 7 and the Austrian Norm ÖNORM B 5320 are based on these quality marks.

It is recommended to install the windows flush with the exterior wall as the application of the ETICS is much simpler.

The installation of the windows and doors must be implemented by competent, skilled and trained craft man and under the supervision of a competent and skilled site engineer.

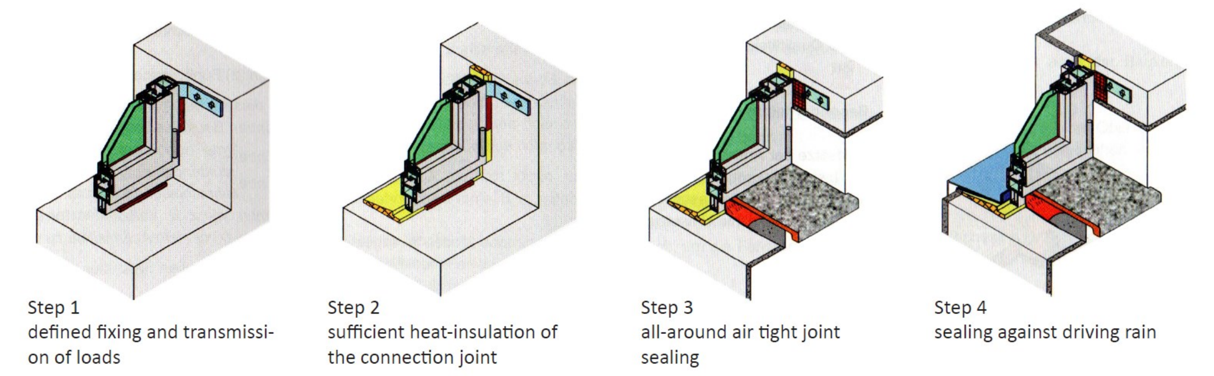



Figure 24: State-of-the-art installation practice of windows and doors – necessary working steps, representing the layer model (see 5.3.2)[37]

### *5.3.2 Refurbishment of a defective/poor installation of (PVC-) windows and doors*

In many public buildings some of the existing windows have been replaced by PVC double glassed windows in the recent years. Experiences show that the quality of the installation is very poor and completely insufficient.

Typically the following installation defects can be observed (see Figure 25 and Figure 26):

- Heat insulation cannot be applied to the window reveal due to the lack of space. The window reveal shall be covered with at least 3 cm of heat insulation, the window frame shall be overlapped.
- No state-of-the-art window sealing has been used to provide a breathable but air- and weather-tight seal (compriband or sealing membranes).
- The new outer window sills have no edge trim to provide a watertight connection to the reveal.
- The gap between frame and reveal is filled with PU-foam, excess foam has not been cut. The PU-foam filling is not covered and therefore not protected against UV- radiation (→ the foam shows obvious decomposition by becoming porous and discoloration)
- The bottom profile rests on wooden fillers, which stand proud to the outside and the inside.
- The window frames have been fixed directly into the wall with simple screws and synthetic plugs instead of wall screws, the PVC- profiles have been partly damaged by the screw fastening.

The inbuilt window achieves not the expected energy saving performance, even if the window itself is of a good thermal quality. Uncontrolled air flow as a result of a not properly sealed joint between the

[37] RAL – Gütergemeinschaft Fenster und Haustüren, Leitfaden zur Montage: 2014-03; Page 14, 15

window frame and the building walls can reduce the energy saving performance of the window system dramatically. A thermal refurbishment though gives the chance to improve the poor installation.


Not enough space to apply a thermal insulation onto the reveal. This window should be either replaced or the reveal has to be cut to make sufficient space for a trowel finished layer and at least 3 cm of heat insulation.

Figure 25: Installation defect: lack of space for exterior wall insulation

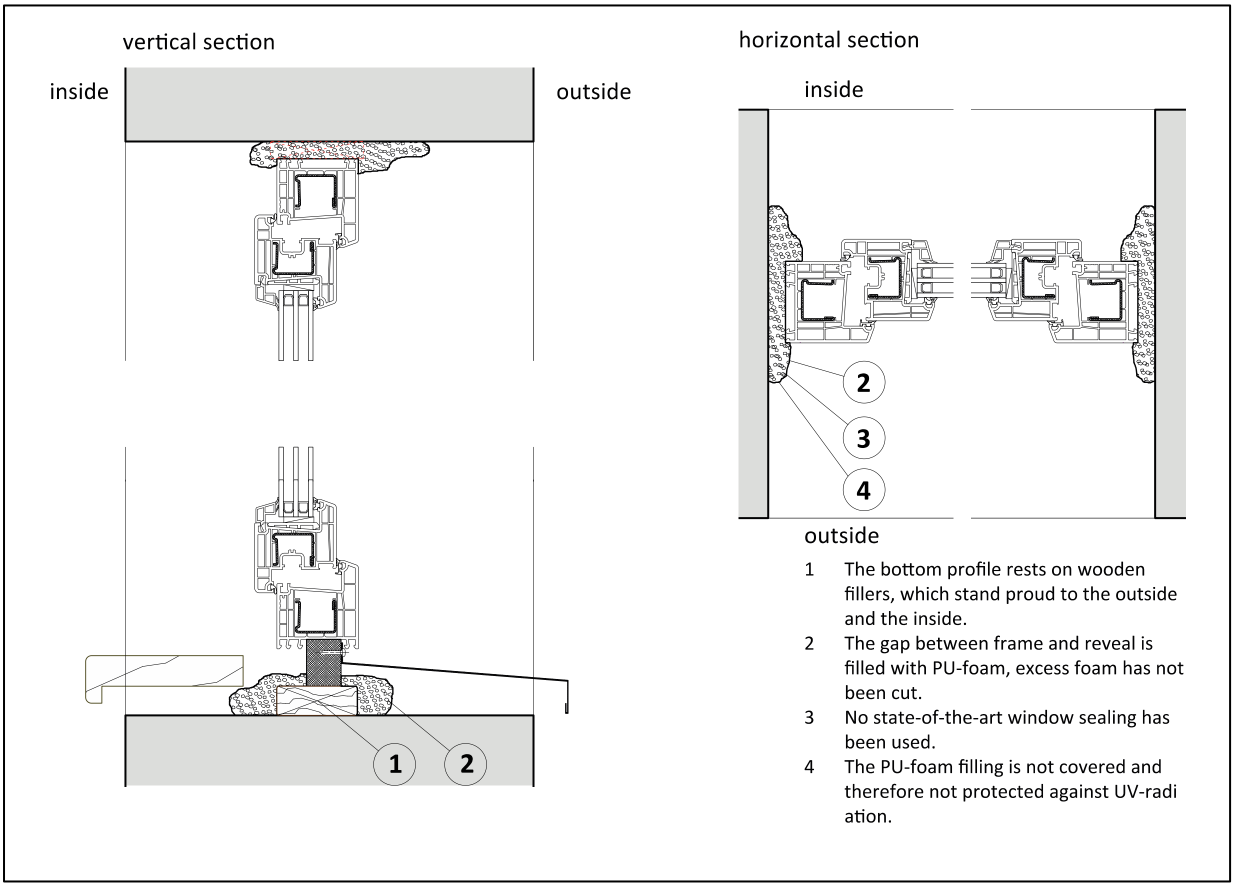



Figure 26: Simplified drawing of a defectively installed window

In order to improve the quality of recently, but incorrect, installed windows the following approach should be applied:

1) Assessment to select the windows, which are feasible to be refurbished and windows, which should be completely replaced. The investigation of deficiencies shall be done accompanied by an authorized representative. This shall be the basis for the later design and tender process.

Recommended criteria's: acceptable energy performance of the window e.g. U-value < 1.3 W/m²K; sufficient space for the application of an external heat insulation onto the window reveal (> 3 cm); proper fixing; no damages; possibility to install properly a new window sill.

**Windows which do not meet the above criteria's should be replaced.**

2) Windows which cannot be properly refurbishes shall be removed. New windows shall be installed according to the recommended installation practices (see chapter 5.3.1).

3) Windows, which are suitable to be refurbished, shall be adopted according to the recommended practiced described below.

**Description of the refurbishment measures**

The removal of defects is very labour intensive and requires beside skilled and well-trained workers a good coordination with the builder, who will apply the ETICS. The legal aspects (claim under guarantee, warranty, etc.) of refurbish recently installed windows must be considered.

Following activities shall be considered:

- Remove the exterior and interior window sills (in case they are already installed).
- Cutting the fillers underneath the bottom profile as close as possible to the frame. Remove all possible heat-bridges like metal fillers, pieces of bricks used as filler, etc..
- Cutting the excess PU-foam and remove damaged and loose parts. Refill remaining gaps with new PU-foam.
- Applying a trowel finished layer (smooth finish) to the existing reveal by using e.g. a reinforcing coat mortar (as it is used for ETICS). The finish shall be applied as close to the window frame as possible, see Figure 22.
- The window profiles must be cleared from any dirtying (e.g. PU-foam)
- Install a state-of-the-art window sealing consisting of a sealing membrane all round the window on the outside and the inside. The sealing membrane is joined by self-adhesive to the window-frame and bonded to the reveal see Figure 23.
- After the application of the ETICS, state-of-the-art exterior window-sills shall be installed.

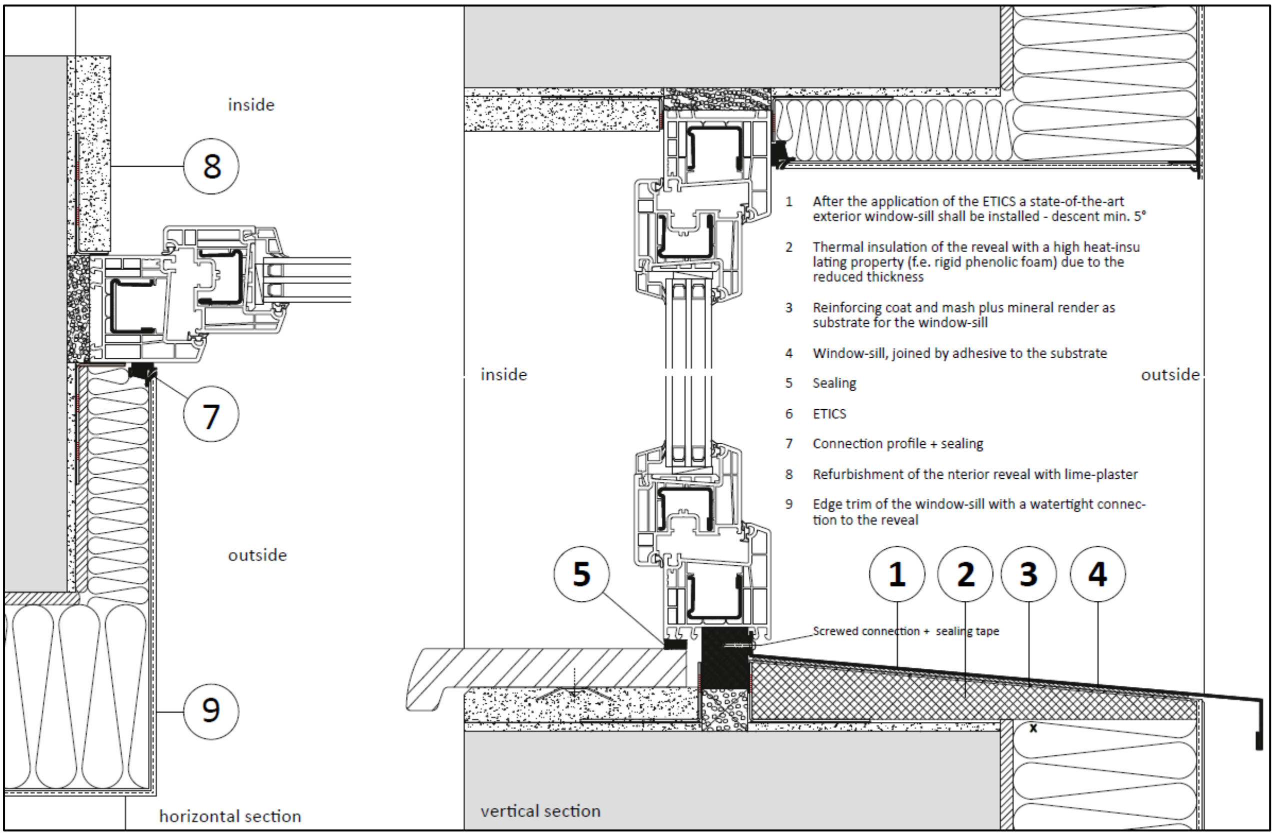



Figure 27: Simplified drawing of a correctly refurbished defective window installation combined with an external thermal insulation composite system (ETICS).

### *5.3.3 Installation practices for window sills*

Following important issues have to be taken into account during the final design of the window sills:

- The material of the window sill should be aluminum.
- The joint of the window sill with contiguous building elements (window frame, reveal, guide rails for solar shading, etc.).
- Window sills, which materials are not watertight (like natural stone) or, which are not shaped trough-like require a second water-carrying sealing-layer.
- Any movements of the window sill (induced by thermal extension or wind/suction loads) shall not be compensated by the façade system (e.g. ETICS), but shall either be absorbed by the sill – system itself (see Figure 32) and / or by installation of a flexible material such as Compriband®, see Figure 33).
- The slope of the window sill shall not be less than 5 degrees; see Figure 29.
- A wedge-shaped insulation block shall be installed underneath the window sill; see Figure 28.
- The overhang of the window sill shall be min. 40 mm (to the finished surface of the façade); see Figure 29.

The recommended installation of window sills with the ETICS can be conducted in two ways:

1. The window sill is installed after the finishing of the ETICS / render: The connection to the window reveal through a sealing-tape (Compriband®). The system is watertight through two water-carrying sealing-layers, see Figure 33.

   Advantage: installation of the window sills do not depend on the installation of the ETICS. Disadvantage: the sealing-tape (Compriband®) is exposed to rain, UV-radiation

2. The window sill is installed together the finishing of the ETICS / render: The end-profiles of the window sills are installed together with the ETICS. The end profiles of the window sills are embedded into the ETICS, see Figure 32.

   Advantage: the window sill is directly embedded into the ETICS
   Disadvantage: installation of the window sills must be coordinated with the installation of the ETICS.

The installation of the window sills must be implemented by competent, skilled and trained staff and under the supervision of a competent and skilled site engineer.

The figure below shows the adhesion agent on top of the second water-carrying sealing layer (base coat + glass fibre mesh reinforcement). The window sill is glued onto the substrate. A sealing-tape or an adhesive sealing is used for the connection of the render to the bottom base-profile of the window-frame.

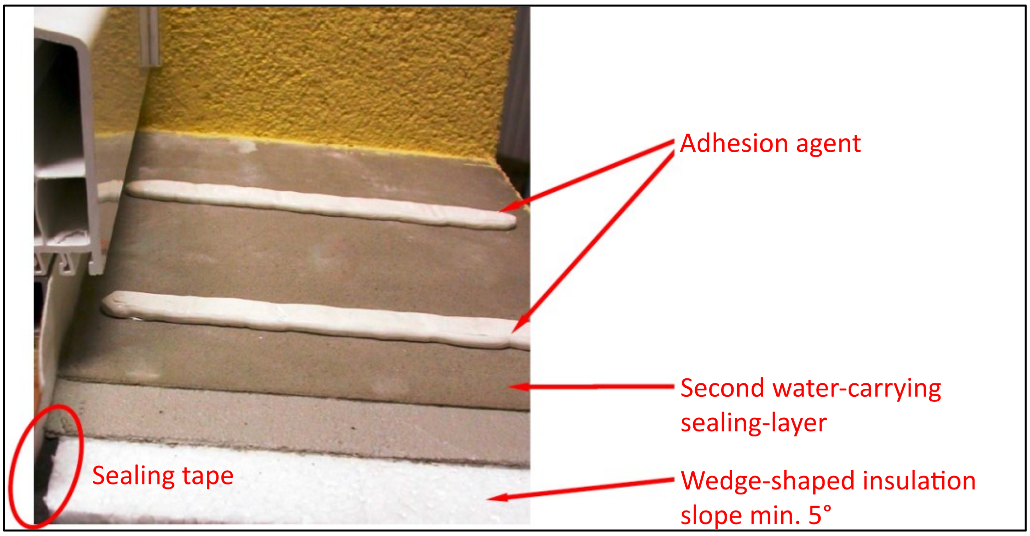



Figure 28 Adhesion agent on top of the second water-carrying sealing-layer on to which the window sill will be glued. [38]

The following figure shows the schematic drawing of the overhang of an aluminum window sill and it’s connection to the window-frame with a sufficiently high base-profile.

The min. height of the base-profile shall be 30 mm in the case the window sills are preassembled together with the ETICS. In case the window sill is installed after the finishing of the ETICS / render the min. height shall be 50 mm.

[38] „Richtlinie Fensterbank, für den Einbau in WDVS- und Putzfassaden sowie in vorgehängten Fassaden“, published by: Österreichische Arbeitsgemeinschaft Fensterbank; 2nd edition, 02.05.2014

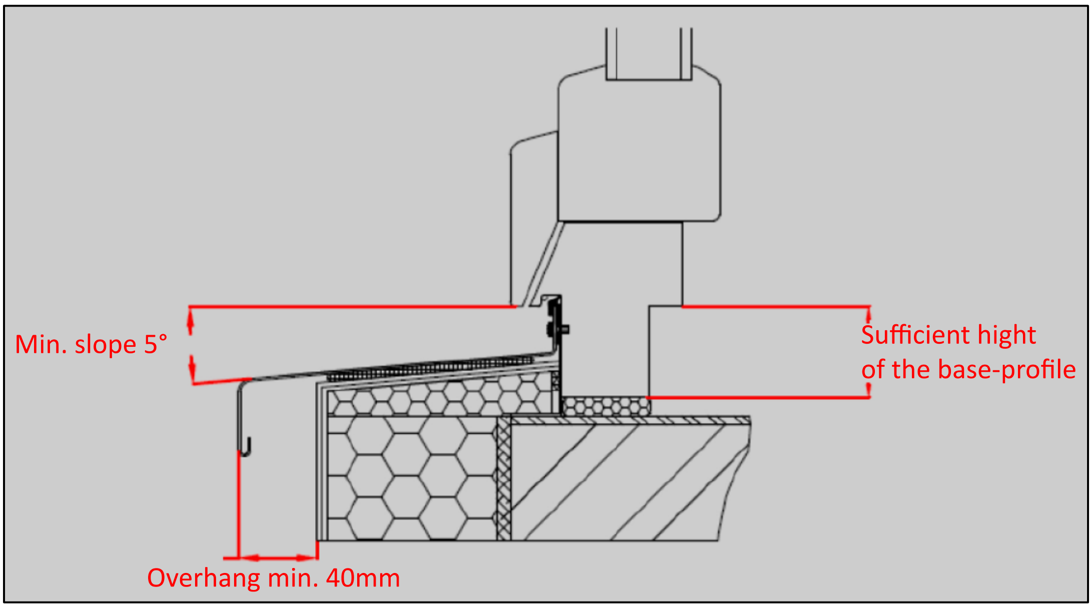



Figure 29: Schematic cross section of the window sill installation

The min. slope of the windowsill must be 5°. The overhang shall be not less than 40 mm. The water outlets for dewatering of the window-profiles shall not be closed by mounting the window sill.

The following figure shows a sealing tape (Compriband®), which is used for the connection of the window-sill to the bottom base-profile of the window-frame.

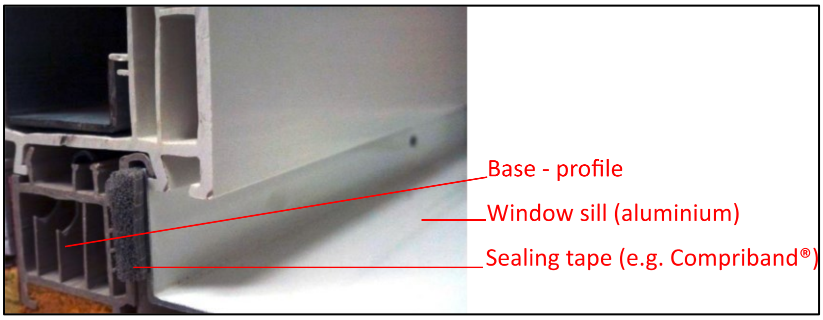



Figure 30: Compriband for the connection window frame – window-sill

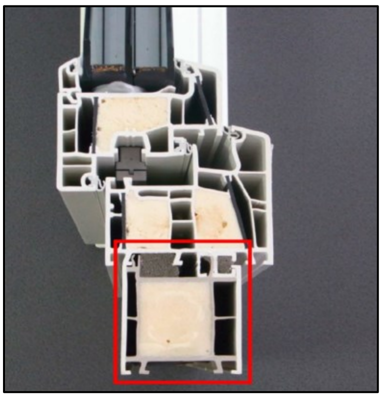


Figure 31: Example of a window with a sufficiently high and insulated base-profile

## 5.4 Selected construction details

### *5.4.1 Overview of window sill formation[39]*

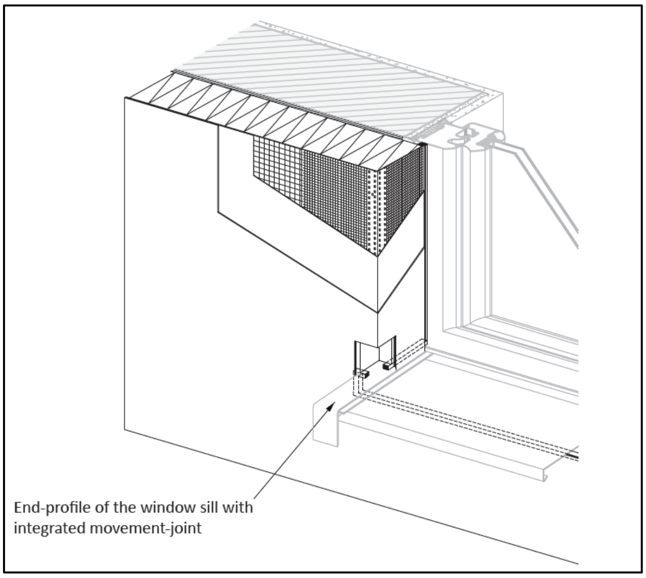



Figure 32: Installation of the window sill and end profiles together with the ETICS

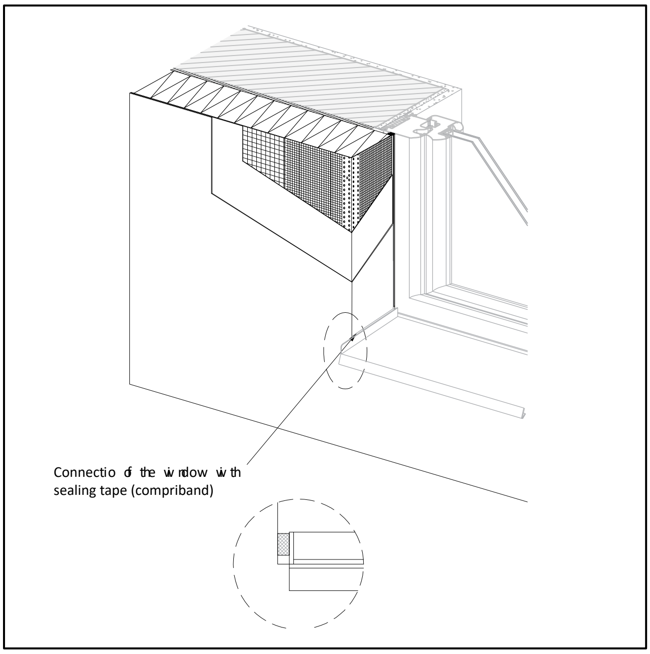



Figure 33: Installation of the window sill with a Compriband after the ETICS have been applied

### *5.4.2 Window sill connection with subsequently installed[40] ETICS*

[39] European Guidelines for the Application of ETICS, annex 2detail drawings, page 73
[40] European Guidelines for the Application of ETICS, annex 2detail drawings, page 75

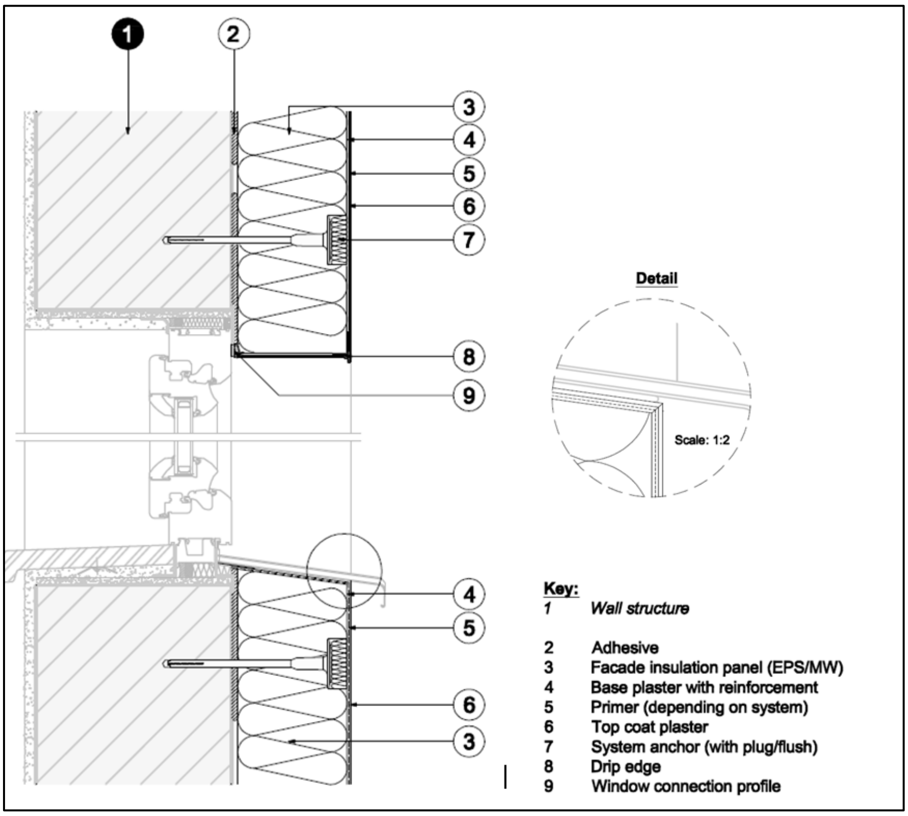



Figure 34: Window sill connection with subsequently installed ETICS

### 5.4.3 Connection to windows and doors with recessed reveal[41]

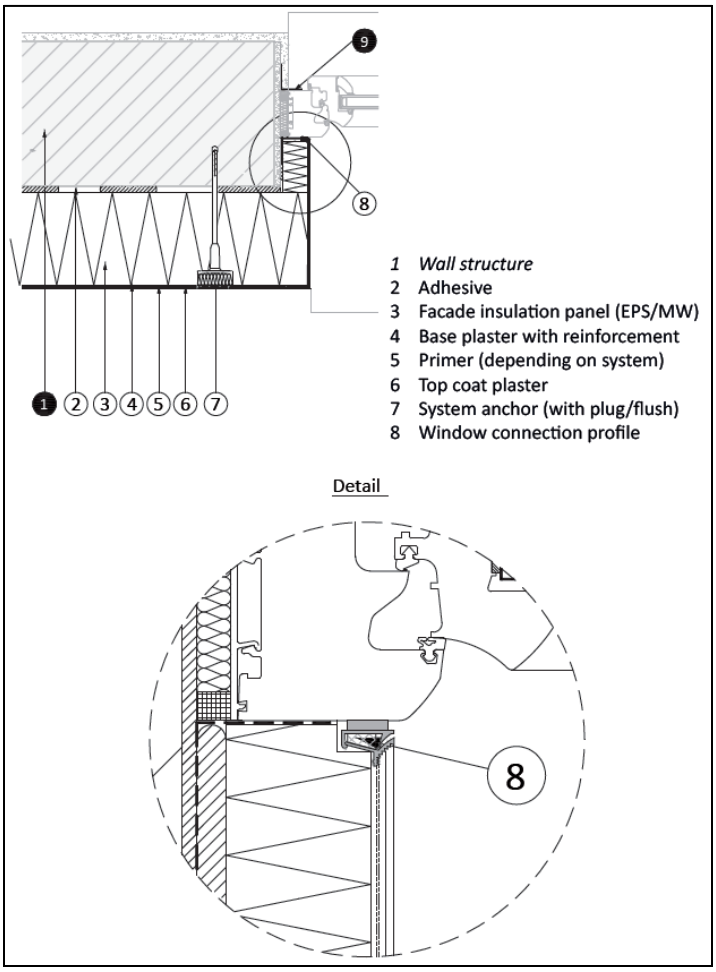



Figure 35: Connection to windows and doors with recessed reveal

[41] European Guidelines for the Application of ETICS, annex 2detail drawings, page 76

### 5.4.4 Connection to windows and doors flush with the brickwork[42]

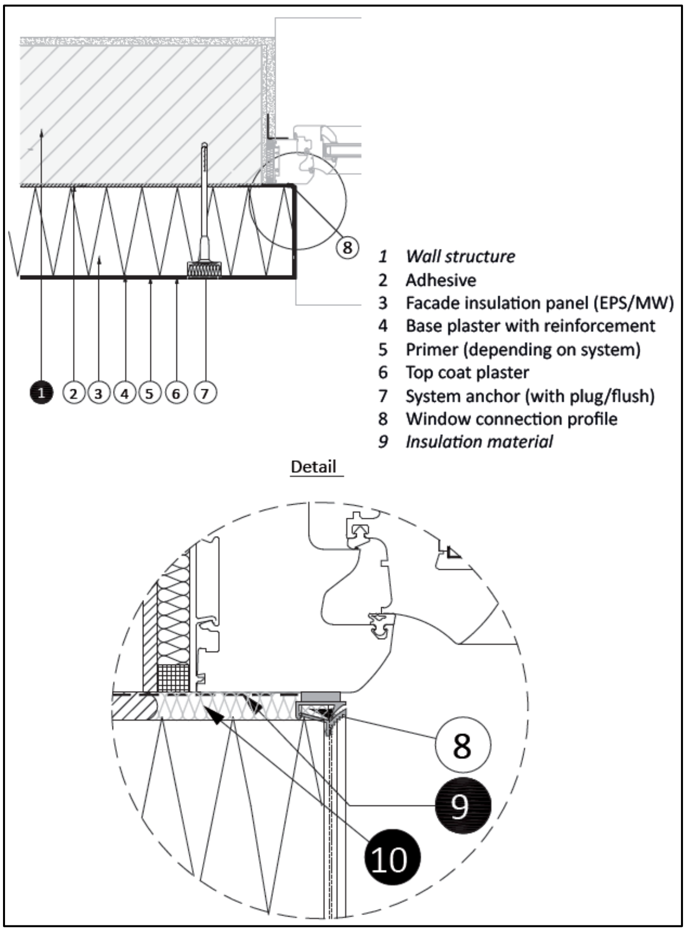



Figure 36: Connection to windows and doors flush with the brickwork

[42] European Guidelines for the Application of ETICS, annex 2detail drawings, page 77

# 6 Refurbishment of the basement ceiling

## 6.1 Typical refurbishment measures for the basement

In case of an unheated basement the ceiling of the basement shall be heat-insulated to provide a continuously insulated building shell. The insulation shall be applied from underneath. There are several insulation systems on the market, which are suitable for this application. It is important to regard following issues carefully beforehand:

- The basement ceiling must be dry (not exposed to moisture).
- The exposure to moisture of the basement in general shall be low.
- The basement must be cleared in order to provide the necessary working space.
- The future utilization of the basement (storage, workshops, etc.) defines the selection of the insulation system.
- The basement must be well naturally ventilated.
- Local legislation especially concerning fire protection.
- All unused pipes, ducts and cables shall be removed.

## 6.2 Requirements for materials

The most common insulation materials used are mineral wool boards, either rock- or glass- wool.

The main requirements are:

- Diffusion open
- Incombustible
- Resistant to moisture
- A finishing cover, which binds the fibres of the mineral wool boards to prevent an unobstructed spreading into the air. This could either be a lamination with a non-woven fabric, a layer of plaster or wood-wool finishing-cover.

It is recommended to use a two-coat Insulation board consisting of an incombustible wood-wool finishing-cover (t=10 mm), which also works as the visible underside and an incombustible rock-wool board. The total thickness of the board depends on the U-value, which must be achieved. The boards are available from 50 mm – 175 mm. They will be mounted to the ceiling from underneath with special bolts according to the prevailing application specifications. No additional finish treatments are needed.

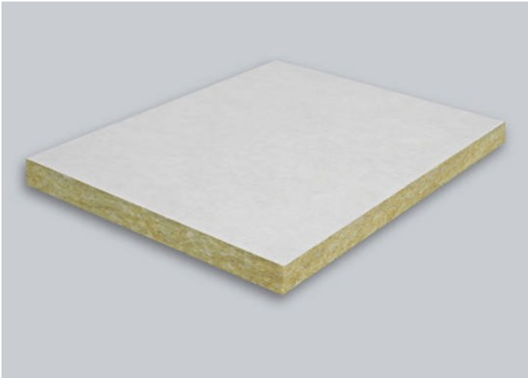


Figure 37: left - two-coat Insulation board with a wood-wool finishing-cover[43]; right - rock-wool board with laminated non-woven fabric[44]

## 6.3 Recommended installation practices

For the refurbishment of the basement ceiling at least the following activities shall be considered:

- Checking the cohesiveness of the plaster on the ceiling, chipping of loosen plaster and refurbish, smoothening of the surface. Areas of exposed and corroded reinforcement steel (e.g. a prefabricated ceiling) shall be renovated before attaching a new plaster (de-rusting of the reinforcement, coating with a corrosion inhibitor, installing a bonding course, filling with repair mortar).
- Insulation of the basement ceiling from underneath with 10 cm of composite insulation boards (two-layer wood wool insulation board with mineral-bonded nonflammable wood wool cover layer, and a non-flammable rock wood board). Commonly different kinds of pipes (sewer, heating, etc.) as well as ventilation ducts are mounted close to or even are suspended from the basement ceiling. Those pipes – if in use and not displaceable – might interrupt a continuous insulation of the ceiling. The interruption shall be kept to a minimum. Especially the edge areas to the outer walls should be well insulated. To avoid heat-bridges at the connection basement - walls and ceiling about 1 meter of the walls shall be insulated top-down. All unused pipes and ducts must be dismounted.

# 7 Rain water management

## 7.1 Typical refurbishment measures for rain water management of buildings

Rainwater-drainage of a roof needs to be provided via internal outlets and downpipes or via external guttering systems or hoppers. Even if a roof is very small, it is recommended there are at least two drainage points in case one becomes blocked. All exterior rainwater downpipes should be led to rain-

[43] The figure shows Heraklith Tektalan® A2-035/2, Knauf Insulation GmbH
[44] The figure shows basement ceiling insulation board DP 6-GVN, Knauf Insulation GmbH

hoppers (see Figure 38, Figure 39), which are connected to the rainwater sewer. Uncontrolled spilling of rainwater can cause severe damages to a building, especially to the facades and the plinth (base insulation). A rainwater management system therefor is essential. It must ensure the removal of the rainwater from the building (incl. ground surface around the building) under all weather conditions.

To properly collect the rainwater a state-of-the-art underground rainwater sewage system shall be installed (PVC or PP[45] pipes). Depending on the surrounding terrain, the ground water level and the nature of the soil might also require a drainage-system around the buildings foundation. The rainwater, which has been collected in a rainwater-sewer can either be:

- Passed into a public sewer system (if approved by the authorities).
- Collected in a rainwater cistern for general purposes.
- Passed into a drainage well. The size of the drainage well must be designed according to the soil conditions on the site.

Minimum diameter of underground rainwater sewer pipes: 150 mm. The sewer has to be laid to fall. Manholes have to be installed in regular distance to ensure maintenance.

Following European norms can be adduced:

- EN 12056-3: Gravity drainage systems inside buildings - Part 3: Roof drainage, layout and calculation
- EN 752: Drain and sewer systems outside buildings

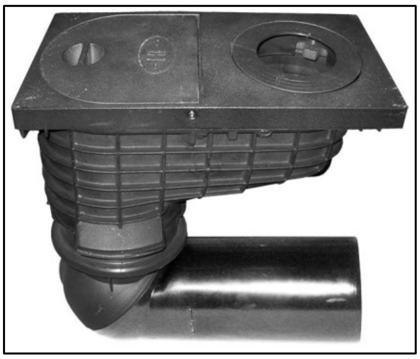


Figure 38: Standard rain hopper with a PP- body, ball joint, inspection cover, leaf collector, trapped (in case it is connected directly to a sewer for foul and surface water) or untrapped.[46]

[45] PP = polypropylene
[46] The picture is taken from: http://www.hutterer-lechner.com

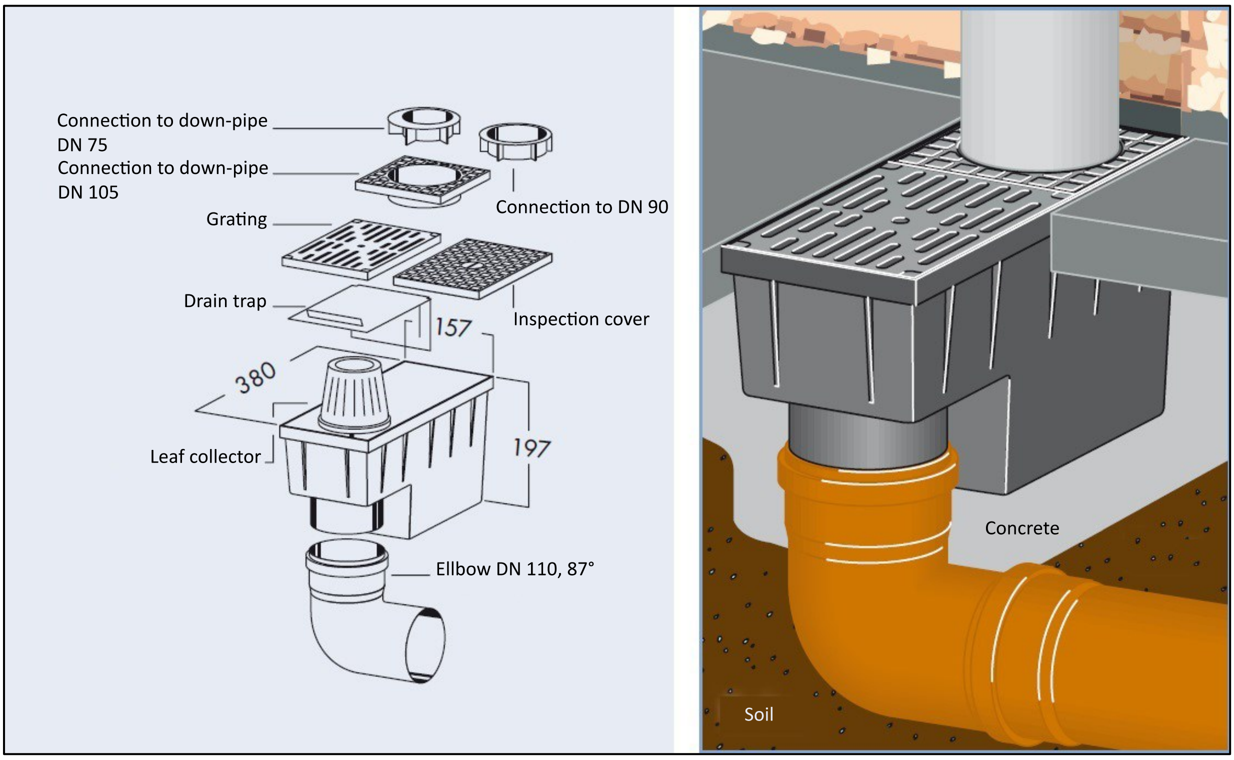



Figure 39: Schematic drawing of an installed rain hopper with an additional outlet for surface water[47]

# 8 Ventilation

The purpose of the general ventilation[48] of public and residential buildings is to provide an adequate supply of fresh air for persons using an area in a building and to remove water vapour and other pollutants that are released throughout the building.

In order to do so a certain amount of fresh air, also called ventilation rate, must be supplied/extracted to/from the building. The ventilation rate for existing public and residential buildings depends mainly on the type of users (children or adults), type of activity/usage (office or sport hall etc.) and the expected quality of indoor air quality. National as well as international standards should be used to calculate the correct and sufficient ventilation demand.

International standards such as EN 15251 or EN 13779 provide the basis for the correct ventilation rate in a building or a room. EN 15251 defines the ventilation rate according to 3 Categories describing

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[47] The schematic drawing is taken from: http://www.marley.de; the descriptions have been translated to English by the authors

[48] Beside the general ventilation other purposes can be relevant: removal of heating/cooling loads in order to maintain a comfortable indoor temperature for building users; removing excess water vapour from areas where it is produced in significant quantities, such as kitchens, bathrooms etc. to reduce the likelihood of creating conditions that support the growth of mould, harmful bacteria, pathogens and allergens; and to limit the concentration of harmful pollutants in the air within the building.

the expected indoor environment (CAT I: high level; CAT II: normal level; CAT III: acceptable level) and 3 categories describing the polluting level of the building (very low; low; non-low).

**Example for the ventilation rate in an office room according to DIN EN 15251:**

| Type of usage | Quality requirement | Building pollution level | Ventilation rate |
|---|---|---|---|
| Office 15 m²; 3 persons | CAT II (normal expectations to the indoor environment) | Low polluting building (existing building) | $q_{tot}$ = 25.2 m³/h/person + 2.52 m³/h/m²<br>→ $q_{tot}$= 113 m³/h for the office |

The estimated fresh air in m³/h may be achieved by natural/manual ventilation or through the supply or extraction of air by mechanical means, or by a combination of these methods. The means of ventilation used has a significant effect on building energy use. The aim should be to provide adequate ventilation while limiting energy use and avoiding occupant discomfort.

**What is natural/manual ventilation?**

Fresh air enters more or less uncontrolled the building or room by natural forces (e.g. winds and thermal buoyancy) drive through building envelope openings and leakages (e.g. unsealed doors or windows). Furthermore building users bring in fresh air by opening of windows and doors. Natural ventilation of buildings depends on human behaviour, climate and the building.

Natural/manual ventilation systems usually requires only a small investment/operational costs but building users are mainly responsible for maintaining the fresh air flow (frequently opening of windows). Natural/manual ventilation systems should be used in areas with low level of polluted air and rooms with a small nr. of people.

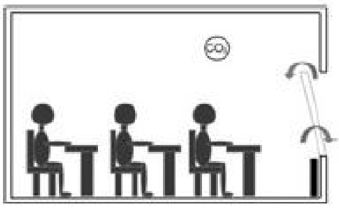
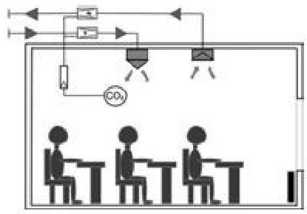
**What is mechanical ventilation?**

Typically a mechanical ventilation system supplies fresh air (and extracts used air) with fans and a duct system which are installed in the building. Mechanical ventilation is used for applications where natural/manual ventilation is not appropriate e.g. large buildings such as public or commercial buildings and in areas with a high level of polluted air such as kitchens, sanitary rooms, etc..

Mechanical ventilation systems ensuring the required ventilation demand in the building and maintain a comfortable and healthy indoor environment for the building users.

Mechanical systems require not only high investment cost, but also considerable operation costs (electricity) and maintenance costs to fulfil hygienic requirements. Heat recovery systems integrated in mechanical ventilation systems can reduce energy costs for heating considerable.

The following figure demonstrated the differences between natural/manual ventilation and mechanical ventilation systems in a school classroom.

| Natural/manual ventilation | Mechanical ventilation system |
|---|---|
| <br>The picture illustrates manual ventilation of a school class by opening of the window. | <br>The picture above illustrates mechanical ventilation of a school class by a centralised ventilation system |
| <u>Components:</u><br>Manual ventilation: -<br>Natural ventilation: building openings (shafts, etc.) | <u>Components:</u><br>ventilation unit (filters, fans, heat recovery system, etc.), metal duct system, flaps, air outlets, air inlets, sensors, control devices etc. |
| <u>Investment costs:</u> low | <u>Investment costs:</u> high |
| <u>Operation costs</u> (electricity, maintenance): low | <u>Operation costs</u> (electricity, maintenance): high |
| <u>Costs for heating:</u> high | <u>Costs for heating:</u> low (when using heat recovery systems) |
| <u>Indoor environment:</u> usually poor<br>Building users are responsible for indoor air quality (e.g. frequently opening of windows) | <u>Indoor environment:</u> usually good<br>Indoor climate is ensured by the mechanical system. |
| <u>Risk</u> of condensate and mold growth: high | <u>Risk</u> of condensate and mold growth: low |
| <u>Recommendations:</u> small buildings, trained building users how to ventilate the building | <u>Recommendation:</u> used for larger buildings such as schools, hospitals, festival halls, larger offices, etc. |

**Interconnection of the building refurbishments and ventilation of the building**

Most of the existing buildings which are foreseen for a thermal refurbishment are in a poor technical condition (leaking roof, poor and leaking windows, etc.). Typically, the ventilation of such buildings "happens" uncontrolled by means of natural ventilation through opening of doors, leakages in windows, etc.. In many cases windows are "sealed" with tapes and cannot be opened for supporting the natural ventilation to improve the indoor air quality. As a result the indoor environment is poor.

**The problem**

When refurbishing such an existing building by replacing the existing windows by new PVC windows, the air infiltration through the windows drops dramatically. Usually building users are not trained in ventilation issues and do not ventilate the building manually by opening windows frequently. Examples show that such a situation can lead in a very short period of time to massive condensate, mold growth and an inacceptable indoor environment. A relative indoor humidity level of > 60% at an indoor temperature of around 20°C will lead to condensate and the risk of mold growth on exterior walls and windows with a surface temperature less than 12°C. Therefore a relative humidity level of more than 60% should be avoided.

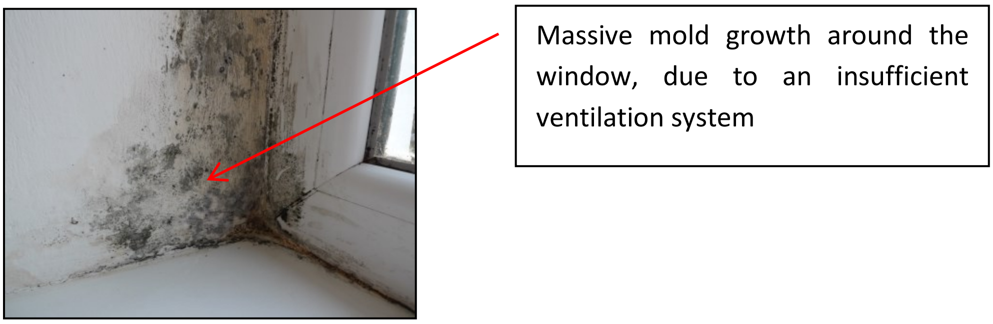



Figure 40: Replacement of windows in a hospital without thermal insulation of exterior walls, poor ventilation system

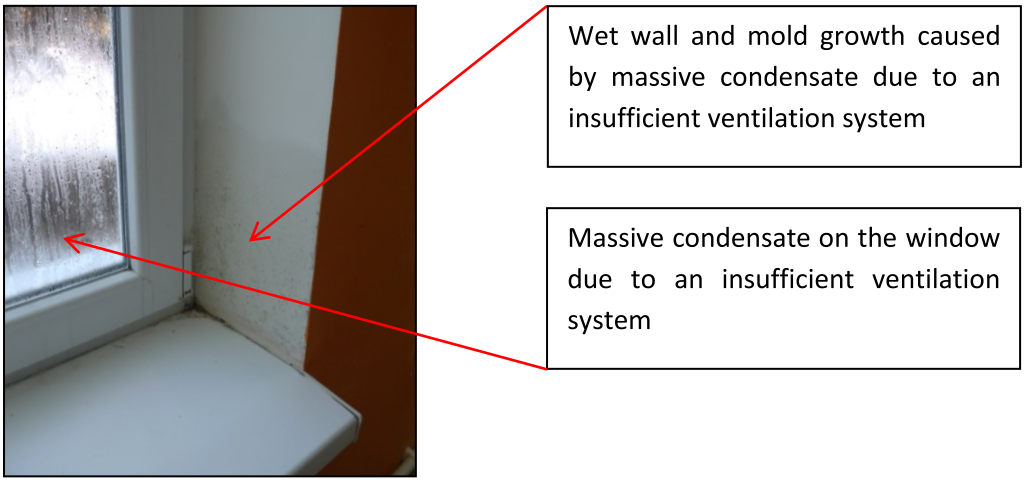



Figure 41: Replacement of windows in a school canteen without thermal insulation of exterior walls, poor ventilation system

**Recommended approach**

In order to achieve and maintain a healthy indoor environment after the refurbishment of an existing building it is recommended to consider the following issues during the project development and implementation:

- Elaboration of a ventilation concept that ensures a correct ventilation rate according to national (and international) standards.
- Integration of a heat recovery system to reduce the energy consumption for heating when considering a mechanical ventilation system.
- Integration of the ventilation concept into the technical design of the building refurbishment project.

- Avoidance of thermal bridges.
- Training of building users in ventilation of the building.
- Carefully maintenance of mechanical ventilation systems (training).