Beton

Planungsatlas für den Hochbau

Introduction

Content

1 General remarks

With the development of timely buildings, the planner has to meet a number of requirements that need to be coordinated. In addition to requirements in the fields of design and statics, especially energetic quality has been focused over the last few years. Therefore, a consideration of energetic requirements in a very early planning stage nowadays is inevitable.

It is necessary to have accurate information about the energetic properties of building components in every planning phase. This is also important to be in line with actual and future requirements regarding thermal insulation and to achieve a balance between thermal and economical effectiveness of thermal insulation measures. Beside the reduction of heat losses through transmission through “undisturbed” building elements, the minimization of edge effects (punctual and lineal thermal bridge effects) is the main issue.

Against this background, this planning atlas embodies a valuable help to the planning architect, engineer, surveyor, client and craftsman by extensively assembling construction details of residential and non-residential buildings relevant for the construction with concrete.
Anticipated heat losses at geometrical or material-conditioned thermal weaknesses in construction details like shutter boxes, balcony connections or wall connections with base plates can already be revealed, analysed and specifically minimised during the planning stage.

Special attention is paid to the sustainability of buildings under energetic points of view. The range of varieties shown in text and picture extends from the currently refurbished buildings over associated standards to passive-house constructions.

This new edition of the planning atlas covers 1 100 construction details. Extensive information is included, e.g. blueprints, data sheets with energetic data, tender texts as well as thermal images and parameters necessary for the calculation of thermal insulation.

2 Fields of application

The details have been chosen under functional, creative, structural and building physical aspects. Especially thermal insulation has been optimized to the state of the art.

Based on detailed information of the constructions and the results of thermal calculations given for every junction in optical and tabular form it is possible for the planner

- to fast and easily look for detailed solutions,
- to furnish detailed energetic proof by giving ψ-values,
- to initiate a minimization of heat losses by choosing optimised construction details and
- to reduce the risk of mould formation.

3 Scope of this work

Main goal of this atlas is to support and to facilitate the daily work of architects and engineers by giving suggestions for construction details for buildings built in massive construction.

For this purpose, this atlas covers different types of constructions typically used for residential and non-residential buildings made of concrete. Here, wall structures are organized in

- single-leaf walls made of standard concrete with an external thermal insulation composite system (ETICS)
- single-leaf walls made of lightweight concrete with an external thermal insulation composite system (ETICS)
- double-leaf cavity walls made of standard concrete with core insulation
- single-leaf monolithic walls made of lightweight concrete brickwork
- walls made of sandwich elements from reinforced concrete
- Large-format suspended concrete facade

The shown detailed solutions can also independently from the frontage be used for constructions like

- precast and semi-precast constructions as well as
- brickwork made of small- and large-size concrete blocks

and can be transferred on various other brickwork materials if designed similarly in construction.

This work covers numerous thermal bridges, e.g.

- eaves, verges and ridges of pitched roofs
- edges of flat roofs
- crests of inclined flat roofs
- outside wall corners to outside air
- outside wall corners to soil
- joints of ceilings and outside walls
- joints of ceilings and basement outside walls
- thermally separated overhanging ceilings / balcony resp. trough slabs
- thermally not separated overhanging ceilings / balcony resp. trough slabs
- loggias, oriels, balconies, terraces, passages
- base plates in the base area
- basement foundations with raft footing
- basement foundations with strip footing
- inside walls under pitched roofs to outside air
- inside walls under flat roofs to outside air
- inside walls of a ceiling to unheated room above
- inside walls of a ceiling to unheated room below
- inside walls on a base plate with raft footing
- inside walls on a base plate with strip footing
- inside walls to unheated rooms

4 Thermal bridges

4.1 Definition of thermal bridges

According to DIN EN ISO 10211, a thermal bridge is defined as “part of the cladding where the otherwise uniform thermal resistance is significantly changed by

- full or partial penetration of the cladding by materials with a different thermal conductivity and/or
- a change in thickness of the building components and/or
- a difference between internal and external areas, such as occur at wall / floor / ceiling junctions”

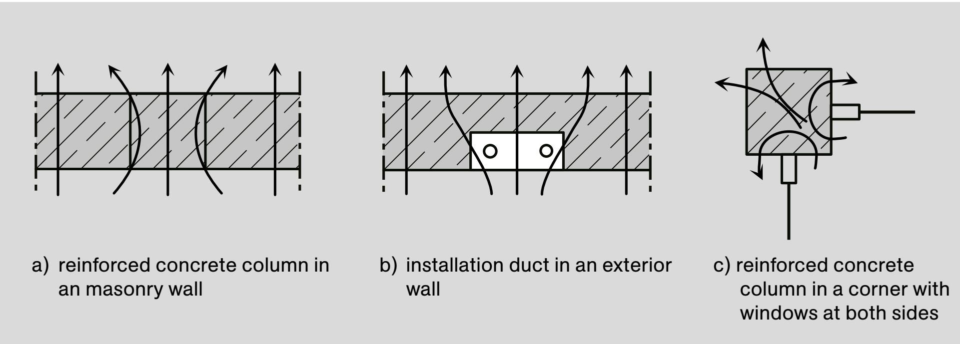

Image 4.1 Examples for thermal bridges

Therefore, a thermal bridge is always a limited local area in the buildings surface with an increased heat flow compared to the “undisturbed” adjacent building elements. Because of the increased heat flow, a thermal bridge implicates a higher heat loss in that area. This limited local area of the thermal bridge is also named “disturbed area” to be linguistically distinguished from the “undisturbed” adjacent building elements.

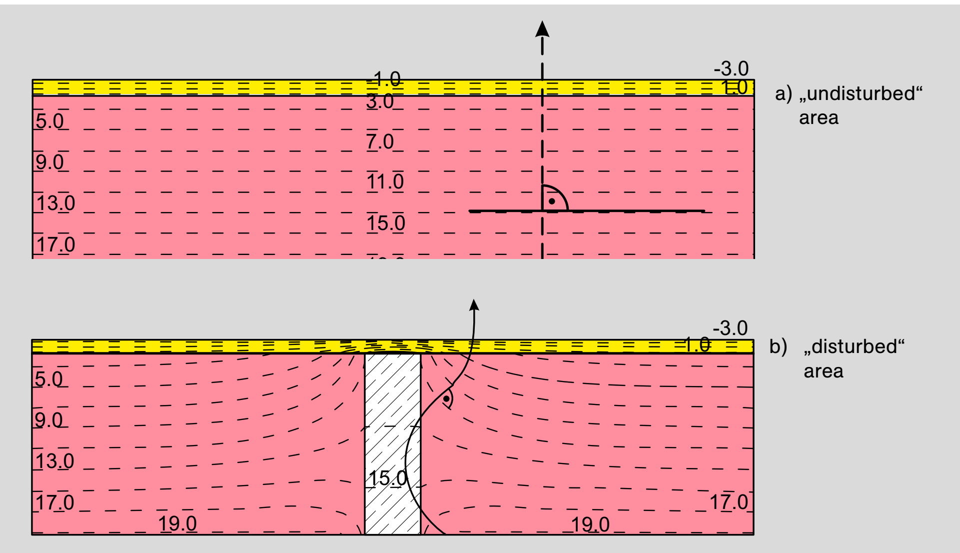

Image 4.2 Isotherms and heat flow

4 Thermal bridges

Considering the temperature field at an “undisturbed” area of the building elements, it should be noted that the isotherms (lines of equal temperature) are running parallel and linear to the surface of the structure. The lines of the heat flux density run perpendicular to the isotherms. However, in the “disturbed” areas the isotherms run as curved lines approaching the surface in joint areas. This leads to a temperature drop in the room.

In the case of bad design of the junction areas, the sum of the occurring heat losses at thermal bridges can make up up to 20 % of the total transmission heat losses. This makes an explicit detailed planning of thermal bridges essential.

4.2 Typecast of thermal bridges

Thermal bridges can be classified into

- geometrical thermal bridges (form-related)
- structural thermal bridges (material-related)
- hybrid forms

Besides, thermal bridges are distinguished in linear and punctate thermal bridges, depending on their form. Linear thermal bridges are areas that extend longitudinally along component junctions. Compared to the building component they are rather thin. In contrast, punctate thermal bridges are areas that are very small compared to the total area.

The additional heat loss is described by the so-called linear thermal transmittance ψ for a linear thermal bridge and the punctate thermal transmittance χ for punctate thermal bridges.

4.2.1 Geometrical thermal bridges

Geometrical thermal bridges, also called form-related thermal bridges, occur where plane parallel building elements show discontinuities, such as the corner of a wall. This effect is based on the relation between the heat supplying inner surface and the heat dissipating outside surface. This has a negative effect if the heat supplying inner surface is smaller than the heat dissipating outside surface. The result is called cooling-rib-effect and occurs for example on outer edges or three dimensional corners of rooms.

4.2.2 Structural thermal bridges

Where building materials with different thermal conductivity lay side by side in the same layer of an envelope component, thermal bridges occur at the transition of the materials. An example is a concrete column in a brick wall.

4.2.3 Hybrid forms

Hybrid forms show a combination of geometrical effects and structural effects. They include for example junctions of wall and base plate above unheated basements, eave-connections to unheated attics and balcony slabs.

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4.3 Consequences of thermal bridges

Thermal bridges may cause two significant effects:

- the increase of heat losses through transmission and
- the reduction of interior surface temperatures

Usually a higher heat loss occurs at thermal bridges. This leads to lower interior surface temperatures compared to “undisturbed” areas. At these locations, there is a potential risk of condensation and mould formation.

If the interior surface temperature falls below the dew point temperature, condensation occurs. This happens for example for a room air temperature of 20 °C and a relative humidity of 50 % at an inside surface temperature of 9.3 °C. Furthermore, the prevention of mould formation is essential for constructive sizing concerning thermal protection. For mould formation to happen, three basic requirements “temperature, humidity and substrate” must be simultaneously given over a certain time. A simplified but usual model for this complex problem fades out the influences of substrate, building material or contaminants. “Prevention of mould formation” has to be ensured by a construction that does not allow for a relative humidity of 80 % on the inside surface to persist. This upper boundary value is usually ensured through a specific minimum surface temperature $\theta_{si,min}$. For the boundary conditions given in DIN 4108-2 (interior temperature of 20 °C, interior relative humidity of 50 %, external temperature of -5 °C) an internal surface temperature $\theta_{si,min.} \geq 12.6$ °C usually prevents mould formation.

Since the lowest interior surface temperatures usually occur near thermal bridges due to increased heat transfer the risk of mould formation or condensation is highest in these areas.

4.4 Consideration of thermal bridges in the Energy Saving Ordinance (EnEV)

4.4.1 Summary of verification procedures

Within a thermotechnical verification based on the German Energy Saving Ordinance (Energieeinsparverordnung – EnEV) the effect of thermal bridges in the area of construction junctions has to be considered in the calculation of heat losses through transmission H_T. This can be done through

- adding general surcharges
- detailed calculation of thermal bridges

4.4.2 General surcharges

One possibility of considering the influences of thermal bridges within a thermotechnical verification according to the EnEV is using a general surcharge “ΔU_{WB}” for the complete heat transferring building envelope.

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- $\Delta U_{WB} = 0{,}15\ W/(m^2 \cdot K)$
  has to be used if more than 50% of a building's outside walls are covered with an inner insulation layer and bonding-in massive ceilings are present.
- $\Delta U_{WB} = 0{,}10\ W/(m^2 \cdot K)$
  has to be used if the above condition does not apply and no specific measures to reduce the influences of thermal bridges are taken.
- $\Delta U_{WB} = 0{,}05\ W/(m^2 \cdot K)$
  can only be used if the relevant construction part junctions are carried out according to DIN 4108 supplementary sheet 2 or verification of equivalence (cf. chapter 4.4.3) has been furnished. If at least one construction detail is not, has not, cannot or could not be designed or carried out according to DIN 4108 supplementary sheet 2 (e.g. because the corresponding detail is not included in supplementary sheet 2) this general surcharge is out of order. Notable thermal bridges here are edges of buildings, embrasures of doors and windows, floor-wall connections, ceiling bearings and balcony slabs.

4.4.3 Verification of equivalence

Should the mentioned reduced general surcharge of U-values of all parts of the building envelope $\Delta U_{WB} = 0{,}05\ W/(m^2 \cdot K)$ be used for the EnEV verification, the detail junctions are to be carried out according to the planning examples of DIN 4108 supplementary sheet 2. Otherwise, a verification of equivalence has to be furnished.

The verification of equivalence is performed as soon as at least one of the following criteria is fulfilled:

- A junction can uniquely be allocated to a detail mentioned in DIN 4108 supplementary sheet 2 considering design, dimensions of material or thermal conductivity.
- If materials are used whose thermal conductivities differ from the details from the supplementary sheet, evidence of an equivalent thermal insulation resistance of the particular layers can be provided.
- Considering the marginal conditions mentioned in DIN 4108 supplementary sheet 2, clause 7 the compliance to the maximum ψ-value mentioned in supplementary sheet 2 can be proved by calculating thermal bridges according to DIN EN ISO 10211. Furthermore, the compliance to a surface temperature $\theta_{si,min.} \geq 12.6$ °C in the most inconvenient place to prevent mould formation has to be proven. This is also done in the detail solutions shown in supplementary sheet 2. The ψ-value may also be taken from publications and manufacturer's directories to be used as reference for comparison. This might be done under the prerequisite that the marginal conditions of supplementary sheet 2 mentioned above have been used to calculate the ψ-value.

4.4.4 Detailed quantification of additional heat losses

In case of a detailed quantification of additional heat losses the surcharge ΔU_{WB} is calculated based on the calculation of the ψ-value (linear heat transfer coefficient) and of the χ-value (point heat transfer coefficient):

$$\Delta U_{WB} = \frac{\sum \chi + \sum \psi \cdot l}{A}$$

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If thoroughly planned the heat loss through transmission can be reduced considerably in this way due to a broad elimination of the amount of thermal bridges. The ψ-value is calculated according to DIN EN ISO 10211 connected to additional technical rules.

NB: When calculating the ψ-value for an energetic verification according to the EnEV the length l the U-value refers to has to be calculated in reference to the external dimensions.

4.4.5 Influence of the thermal bridging surcharge ΔU_{WB}

What influence might the use of the thermal bridging surcharge ΔU_{WB} have versus a detailed calculation?

If one takes a stipulated U-value (e.g. for an outside wall) as a basis a value d_{erf} emerges for the necessary thickness of the insulation layer of the outside wall of the building that depends on the amount of thermal bridges. The thickness of the insulation layer is also calculated for the verification according to the EnEV. Image 4.3 shows the connection between the stipulated U-value, the thermal bridging surcharge ΔU_{WB} and the thickness of the insulation layer of the outside wall.

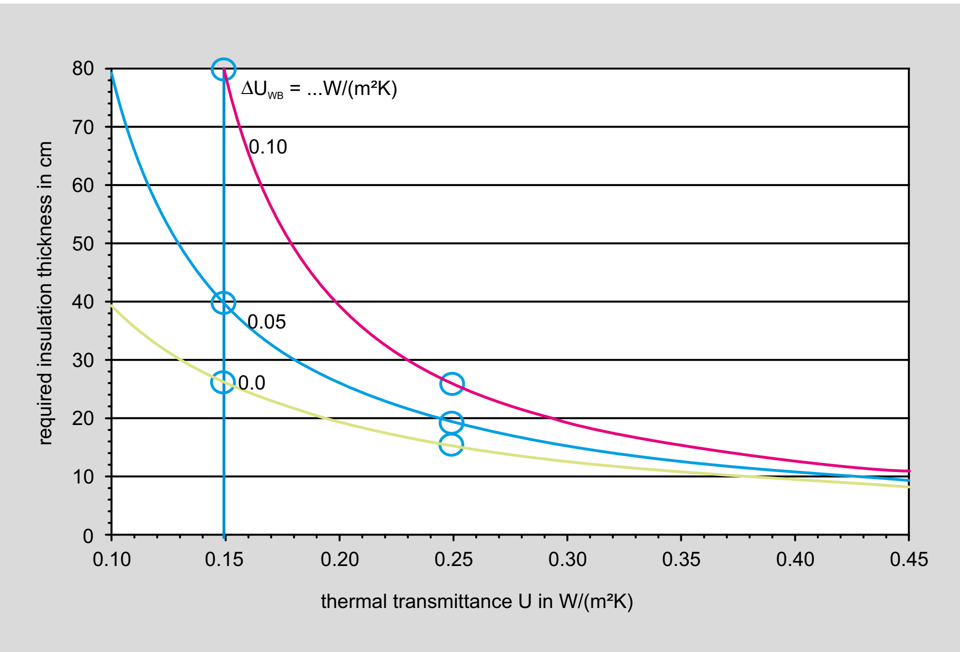

Image 4.3 Influence on the required insulation thickness by the thermal bridge surcharge ΔU_{WB}

It becomes apparent that the required insulation thickness is increasingly influenced by ΔU_{WB} especially at lower U-values.

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4.5 General basis of calculation

4.5.1 Linear heat transfer coefficient ψ

The linear heat transfer coefficient ψ (ψ-value in W/(m·K)) is a quantity describing the influence of a linear thermal bridge on the total heat flow similar to the U-value of standard building elements. The linear heat transfer coefficient is calculated according to DIN EN ISO 10211 with

$$\psi = L^{2D} - L^{0}$$

where

L^{2D} → describes the actual heat loss in the area of the thermal bridge that is calculated by a two-dimensional calculation of thermal bridges

L^{0} → describes the heat loss of an undisturbed building part of the same size
$L^{0} = \Sigma\, U_i \cdot l_i \cdot F_i$

4.5.2 Point heat transfer coefficient χ

Using point heat transfer coefficients χ (χ-value in (W/K)) heat losses in selective areas can be calculated.

$$\chi = L^{3D} - \Sigma\; L_j^{2D} \cdot l_j + \Sigma\, U_i \cdot l_i$$

where

L^{3D} → is the thermal conductance obtained from a 3D calculation of the 3D component being considered separating the two environments [W/K]

L^{2D} → is the thermal conductance obtained from a 2D calculation of the 2D component j being considered separating the two environments [W/K]

L_j^{2D} → is the thermal transmittance of the 1D component i being considered separating the two environments; [W/m²K]

U_i → is the length over which the value L_j^{2D} applies [m]

l_i → is the length over which the value U_i applies [m]

4.6 Marginal conditions for calculations

4.6.1 General Annotations

The boundary conditions used for the calculations of this atlas are taken from the DIN 4108 supplementary sheet 2. Supplementary sheet 2 regulates temperatures and thermal resistances that are used with the models as well as construction dimensions that are to be considered in the calculations.

Especially for ground-coupled construction details, the boundary conditions of DIN 4108 supplementary sheet 2 partly differ from those described in DIN EN ISO 10211. These deviations lead to the question if ψ-values calculated according to DIN 4108 supplementary sheet 2 can be used for detailed thermal bridge calculations according to DIN EN ISO 10211 regardless of the verification of equivalence. Comparisons between the different calculation types show that the results of a calculation according to DIN 4108 supplementary sheet 2 always are ”on the safe side“ as against those of DIN EN ISO 10211. It is therefore tenable to take the values stated in this atlas for a detailed calculation of ground-coupled construction junctions.

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4.6.2 Boundary temperatures

The boundary temperatures used in the calculations of heat flow and surface temperature have been taken from DIN 4108 supplementary sheet 2 and are illustrated in the table below. Further details can be gathered from the standard mentioned above.

Table 4.1 Boundary temperatures for calculations of thermal bridges according to DIN 4108 supplementary sheet 2

Location	Purpose of the calculation	
	surface temperatures	**heat flow**
Internal		
general	θ_i = 20 °C	θ_i = 20 °C
in unheated rooms	θ_u = 10 °C	θ_u = 10 °C
in unheated attics	θ_u = - 5 °C	θ_u = 0 °C
External		
outside air	θ_e = - 5 °C	θ_e = - 5 °C
soil	θ_G = 10 °C	θ_e = 5 °C

NB:
The minimum surface temperatures have been determined based on the boundary conditions of DIN 4108 supplementary sheet 2 for calculating f-values. All details have been checked to fulfil the above mentioned requirement of $\theta_{si,min}$ ≥ 12.6 °.

4.6.3 Thermal resistances

Thermal resistances (cf. DIN EN ISO 6946 resp. DIN EN ISO 13788) have been set according table 4.2.

Table 4.2 Thermal resistances R_{si} and R_{se}

	R_{si}	R_{se}
Calculation purpose heat flow		
heat flow upwardly	0.10	0.04
heat flow horizontally	0.13	
heat flow downwardly	0.17	
Calculation purpose surface temperatures		
heated rooms	0.25	0.04
unheated rooms	0.17	
glazings	0.13	

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4.6.4 Geometrical boundary conditions

The dimensions of the calculation models match DIN 4108 supplementary sheet 2.

Table 4.3 Dimensions of the calculation models according to DIN 4108 supplementary sheet 2.

Direction	Calculation purpose	
	surface temperatures	heat flow
Distance to horizontal cut-off plane inside the building	at least 1 m	at least 1 m
Distance to horizontal cut-off plane outside the building	at least 1 m	According to DIN 4108 supplementary sheet 2 no soil has to be included in the calculation model. The system boundaries have to be set along the construction element's outside surface.
Distance to vertical cut-off plane below ground floor level	3 m or 1 m, if floor level > 2 m below surface of the soil	

4.6.5 Heat transfer coefficients of undisturbed building elements

For a calculation of the ψ-value a calculation of the U-values of the undisturbed building elements is required. The U-values in the Planungsatlas Hochbau have been calculated according to the standards mentioned in Table 4.4. Further details can be gathered from the mentioned standards.

Table 4.4 Heat transfer coefficients of undisturbed building elements

U value of	is calculated by using
Single- or multi-layered, homogeneous elements	DIN EN ISO 6946
Multi-layered elements consisting of inhomogeneous layers	
Concrete sandwich elements	A self-developed method[1)] based on DIN EN ISO 10211.

[1)] Willems, W. Hellinger, G.: „Exakte U-Werte von Stahlbeton-Sandwichelementen“, Bauphysik 5/2010 p. 275 - 287, Ernst & Sohn Verlag Berlin, 2010

4.6.6 Material characteristics

All thermal conductivities have been taken from DIN EN ISO 10456 resp. DIN 4108-4.

4.6.7 Programme for the calculation of heat flow and temperature

All calculations have been carried out using the software ANSYS (Swanson Analysis Systems Inc.) that uses the finite element method.

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4.7 Recommendations for the minimisation of thermal bridge effects

4.7.1 Avoiding sprawling building enclosures

Sprawling building enclosures (geometrical thermal bridges) should preferably be avoided. The lateral surface of the heated room to volume ratio (A/V) should be minimised.

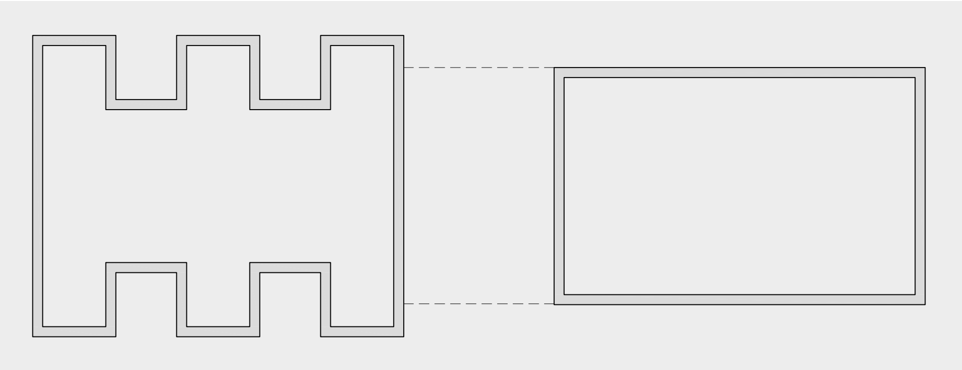

Image 4.4 Depiction of a sprawling (left) and a compact building design (right)

4.7.2 Avoiding sharp corners

Sharp corners (geometrical thermal bridges) should preferably be avoided. The outside to inside surface ratio (A_e/A_i) should be minimised.

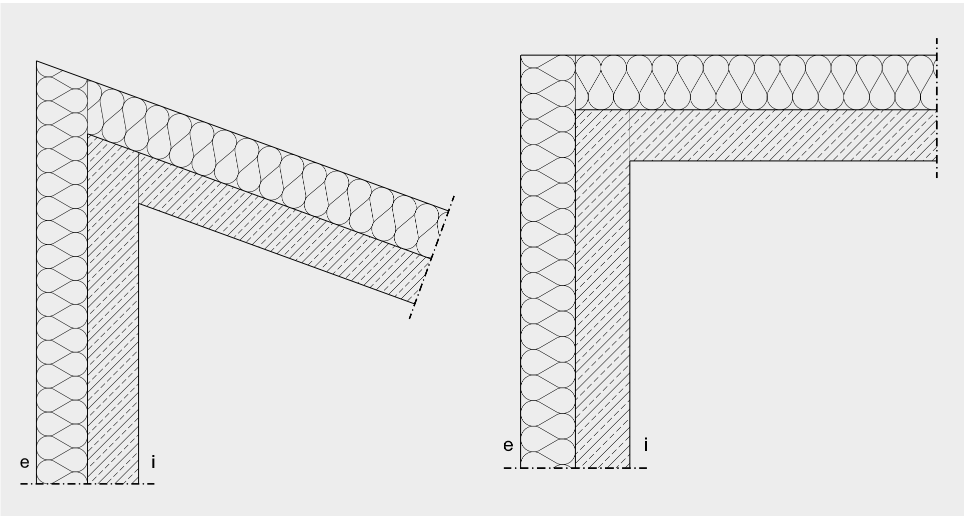

Image 4.5 Depiction of a sharp outside corner (left) and an optimized design (right)

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4.7.3 Avoiding penetration of the insulation layer

If penetrating the insulation layer the assembly of a material with a conductivity as low as possible is advised (e.g. insulating elements at balcony connections).

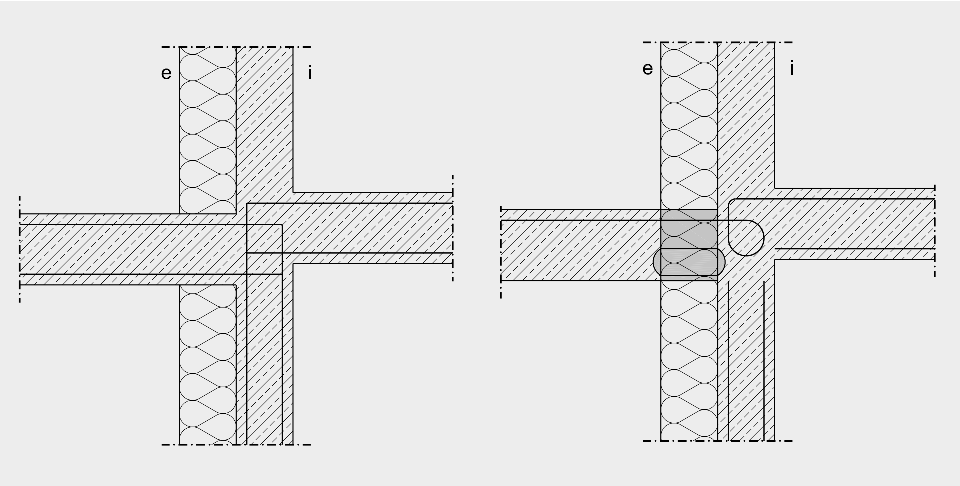

Image 4.6 Depiction of a penetration of the insulation layer without decoupling (left) and the optimised thermally separated connection (right)

4.7.4.Ensuring a continuous insulation layer

It should be possible to completely retrace the insulation layer around the building enclosure with a scaled pencil. This would imply no weakening of the insulation level and the avoidance of “insulation gaps”.

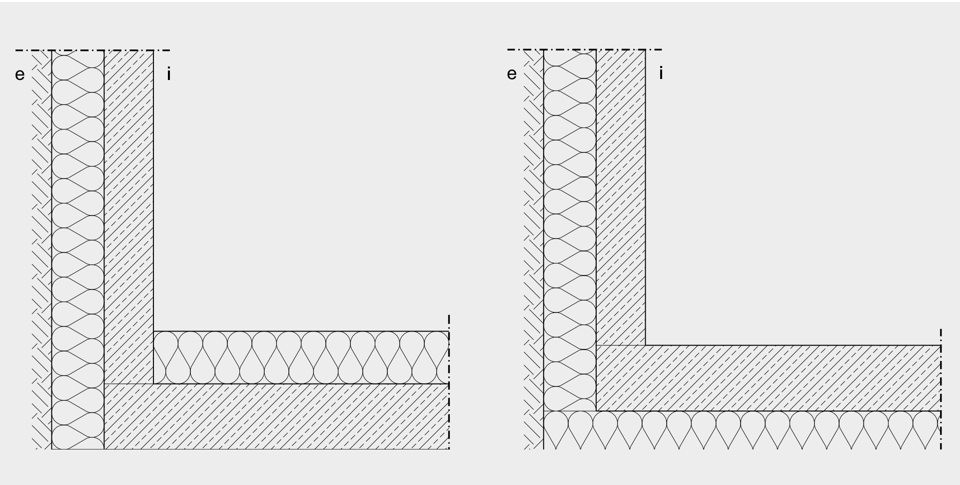

Image 4.7 Depiction of an “insulation gap” (left) and the optimized junction (right)

5 Disclaimer of liability

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