Building physics

Reinforced concrete/reinforced concrete

Steel/reinforced concrete

Timber/reinforced concrete

Steel/steel

Thermal bridges

Definition of thermal bridges

Thermal bridges are local component areas in the building shell, in which heat loss occurs. The increased heat loss results in that the component area deviates from the even shape ("geometric thermal bridge") or in that the component area concerned, local materials with increased thermal conductivity are present ("material-conditioned thermal bridge").

Effects of thermal bridges

In the area of the thermal bridge the locally increased heat loss leads to a lowering of the inner surface temperatures. As soon as the surface temperature falls below the so-called "mildew temperature" θ_S, mould forms. What is more, if the surface temperature falls below the dew-point temperature θ_τ, then the moisture in the ambient air condenses on the cold surfaces in the form of condensate.
If mould has formed in the area of a thermal bridge, then considerable impairments can occur to health for the resident due to the emitted mould spores in the room. Mould spores cause allergies and can therefore provoke allergic reactions in people, such as, for example, asthma. Through the general long-lasting daily exposure in dwellings there is a high risk that the allergic reactions will become chronic.

Summarised, the effects of thermal bridges are thus:

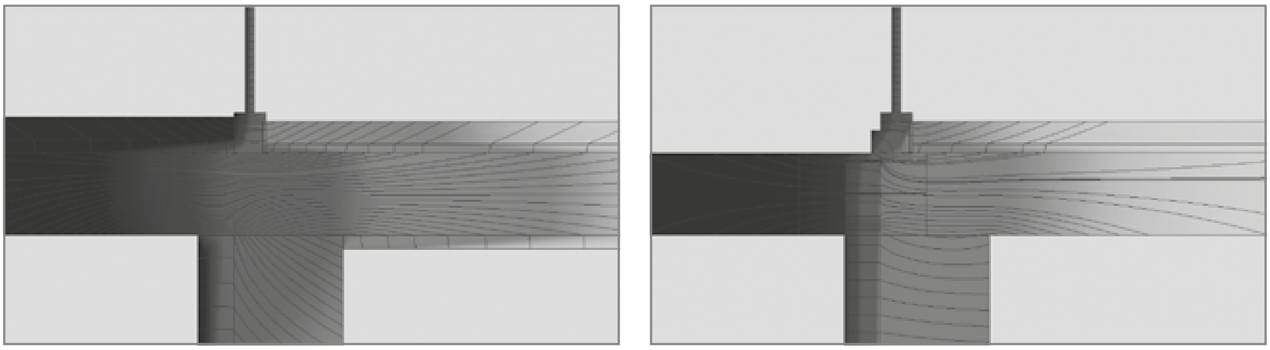
- Danger of the formation of mould
- Danger of impairments to health (allergies etc.)
- Danger of occurrence of condensation
- Increased thermal energy loss

Uninsulated cantilevered structural components

With uninsulated cantilevered structural components such as, for example, reinforced concrete balconies or steel girders, the co-action of the geometric thermal bridge (cooling fin effect of the cantilever) as well as of the material-conditioned thermal bridge (breaching of the heat insulating layer with reinforced concrete or steel), there is a strong heat drainage. With this, cantilevers are among the most critical thermal bridges of the building shell. The results of uninsulated cantilevers are considerable heat losses and a significant lowering of the surface temperature. This leads to a marked increase of heating costs and a very high risk of mould in the area of the connection of the cantilever.

Effective heat insulation using Schöck Isokorb®

The Schöck Isokorb®, through its thermotechnically and statically optimised design (minimised reinforcement cross-section with optimised load-bearing capacity and employment of particularly good heat insulating materials), represents a very effective insulation of the cantilever.



Heat progressions of balcony connections, from dark-coloured, cold balcony to light-coloured, warm internal area.
Left: Continuous reinforced concrete floor without thermal separation. Right: Thermal separation using Schöck Isokorb®

Thermal bridges

Dew-point temperature

The dew-point temperature θ_τ of a room is that temperature at which the moisture present in the ambient air can no longer be held by the room air and is then released in the form of water droplets. The relative ambient air humidity is then 100 %.

The areas of the air layer which have direct contact with the colder structural component surfaces, due to this contact, adopt the temperature of the cold structural component surface. If the minimum surface temperature of a thermal bridge lies below the dew-point temperature, then the air temperature directly at this point will also lie below the dew-point temperature. This has the result that the moisture held in this layer of ambient air is precipitated in the form of condensation on the cold surface: Condensation water “drops out”.
The dew-point temperature depends only on the ambient air temperature and the ambient air humidity (see Figure 1). The higher the ambient air temperature and the higher the ambient air humidity, the higher is the dew-point temperature, i. e. the more easily condensation forms on cold surfaces.

The normal ambient air climate in interior rooms on average is ca 20 °C and ca 50 % relative ambient air humidity. This results in a dew-point temperature of 9.3 °C. In rooms heavily loaded with moisture such as, for example, bathrooms, high humidities of 60 % and more are also reached. The dew-point temperature is correspondingly high and the risk of the formation of condensation increases. Thus the dew-point temperature with an ambient air humdity of 60 % is already 12.0 °C (see Figure 1). You recognise this sensitive dependency of the dew-point temperature on the ambient air humidity very easily from the steepness of the curve in Figure 1: Already small increases of the ambient air humidity lead to a substantial increase of the dew-point temperature of the ambient air. This has as a result a significant increase of the risk of condensation on cold structural component surfaces.

Mildew temperature

The humidity required for the growth of mould on structural component surfaces is already achieved upwards from an an ambient air humidity of 80 %. This means, mould then forms on cold structural component surfaces, if the structural component surface is at least as cold, so that a humdity of 80 % is triggered in the directly adjacent layer of air. The temperature at which this occurs is the so-called “mildew temperature” θ_S.

Mould growth thus occurs already with temperatures above the dew-point temperature. For the atmospheric environment 20 °C/50 % the mildew temperature is 12.6 °C (see Figure 2) thus 3.3 °C higher than the dew-point temperature. Therefore, for the avoidance of structural damage (formation of mould), the mildew temperature is more important than the dew-point temperature. It does not suffice if the interior surfaces are warmer than the dew-point of the ambient air: The surface temperatures must lie above the mildew temperature!

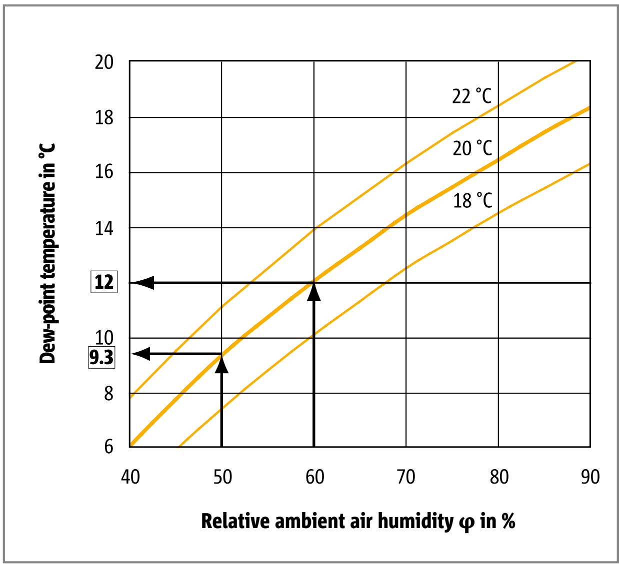


Figure 1: Dependency of the dew-point temperature on ambient air humidity and temperature

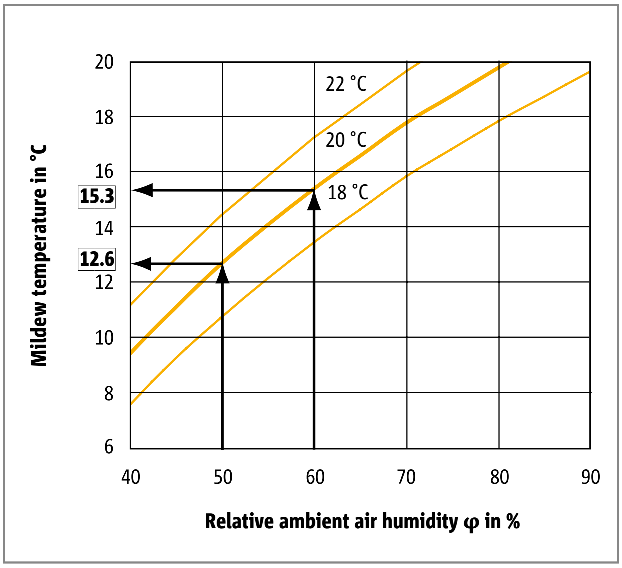


Figure 2: Dependency of the mould temperature on ambient air humidity and temperature

Characteristic building-physical values

Thermal characteristic building-physical values of thermal bridges

Summarised, the effects of thermal bridges are thus:

Thermal effects	Characteristic building-physical values	
	Qualitative representation	Quantitative single value
Mould formation **Condensation result**	Isotherms with temperature scaling	Minimum surface temperature θ_{min} Temperature factor f_{Rsi}
Heat loss	Heat flow lines	ψ-value χ-value

The mathematical determination of these characteristic values is possible exclusively through a thermal FE calculation of the precise existing thermal bridge. For this the geometric build-up of the structure in the area of the thermal bridge is modelled in the computer together with the thermal conductivities of the materials used. The constraints to be applied with the calculation and modelling are regulated in BS EN 10211.

The FE calculation provides, along with the quantitative characteristics, also a representation of the temperature distribution within the structure (isotherm presentation) as well as the progress of the heat flow lines. The representation using the heat flow lines shows on which path through the structure the heat is lost, and it thus allows easy recognition of the thermal weak points of the thermal bridge. The isotherms are lines or surfaces of equal temperature and show the temperature distribution within the calculated structural component. Isotherms are often presented with a temperature step width of 1 °C. Heat flow lines and isotherms are always perpendicular to each (see Figures 3 and 4).

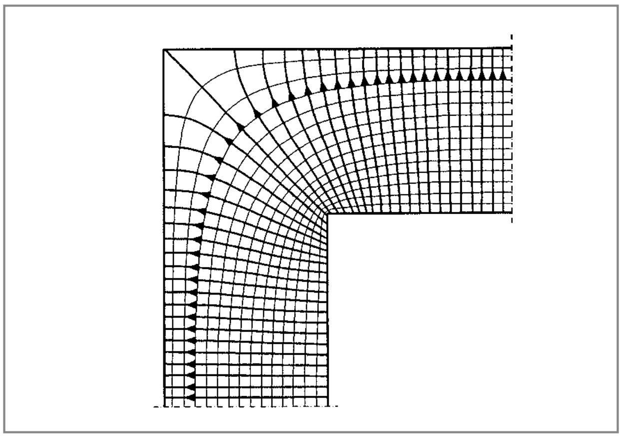


Figure 3: Example of a pure, geometric thermal bridge. Representation of isotherms and heat flow lines (arrows).

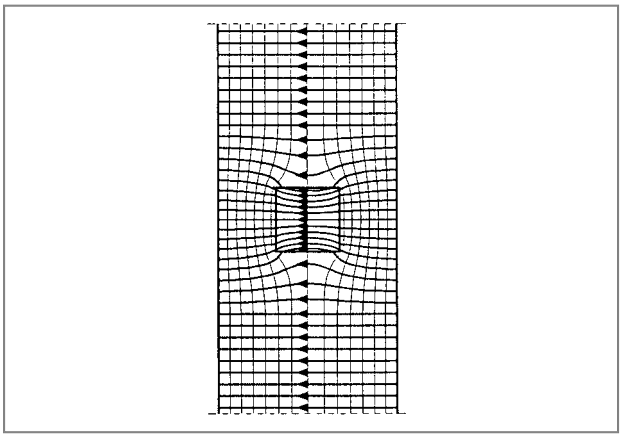


Figure 4: Example of a pure. material-conditioed thermal bridge. Representation of isotherms and heat flow lines (arrows).

Characteristic building-physical values

The minimum surface temperature $\theta_{si,min}$ and the temperature factor f_{Rsi}

The minimum surface temperature $\theta_{si,min}$ is the lowest temperature occurring in the area of a thermal bridge. The value of the minimum surface temperature is decisive for whether condensation occurs on a thermal bridge or mould forms. The minimum surface temperature is thus a characteristic value for the humidity effects of a thermal bridge.

The characteristic values $\theta_{si,min}$ and ψ-value depend on the structural setup of the thermal bridge (geometry and thermal conductivities of the materials forming the thermal bridge). The minimum surface temeprature is, in addition, still dependent on the set outside air temperature: The lower the outside air temperature the lower is the minimum surface temperature (see Figure 5).

The temperature factor f_{Rsi} is also used as an alternative to the minimum surface temperature as humidity characteristic value. The temperature factor f_{Rsi} is the temperature difference between inside and outside (θ_i - θ_e) related to the temperature difference between minimim surface temperature and the outside air temperature ($\theta_{si,min}$ - θ_e):

$$f_{Rsi} = \frac{\theta_{si,min} - \theta_e}{\theta_i - \theta_e}$$

The f_{Rsi}-value is a relative value and thus has the advantage that this is dependent on the design of the thermal bridge and not, like $\theta_{si,min}$,on the applied outside and inside air temperatures. If one knows the f_{Rsi}-value of a thermal bridge then conversely the minimum surface temperature can be calculated with the aid of the air temperatures:

$$\theta_{si,min} = \theta_e + f_{Rsi} \cdot (\theta_i - \theta_e)$$

In Figure 5, with a constant inside temperature of 20 °C, the dependency of the minimum surface temperature on the existing outside temperature is depicted for various f_{Rsi}-values. Depicted in Figure 6 is the relationship between $\theta_{si,min}$ and f_{Rsi}, under the assumption of an outside temperature of 0 °C.

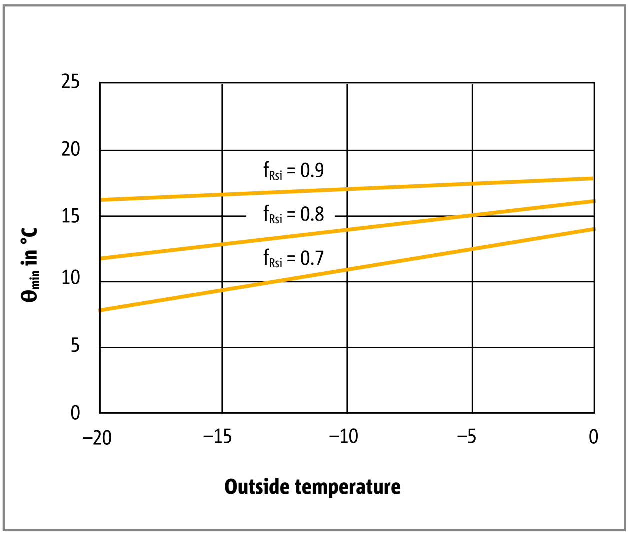


Figure 5: Dependency of the minimum surface temperature on the adjacent outside temperature. Inner temperature constant 20 °C.

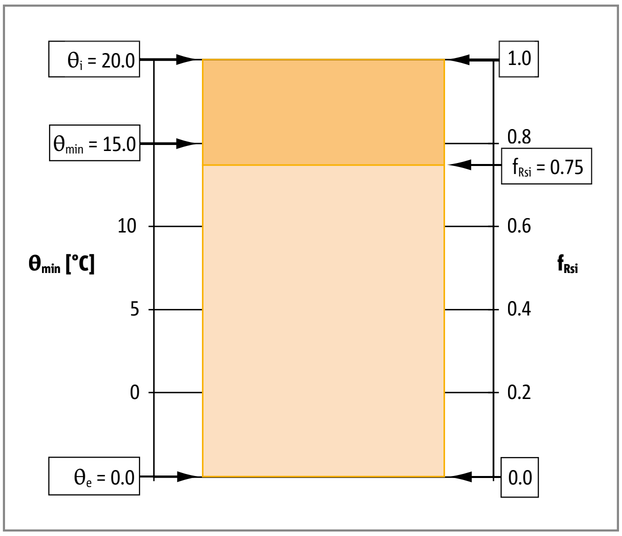


Figure 6: For the definition of the f_{Rsi}-value

Characteristic building-physical values

The thermal transmission coefficients ψ and χ

The linear thermal transmission coefficient ψ ("ψ-value")indicates the per meter run. of additionally occurring heat loss of a linear-shaped thermal bridge. The point heat transmission coefficient χ ("χ-value") indicates the additional heat loss via a point thermal bridge.

Equivalent Thermal Conductivity λ_{eq}

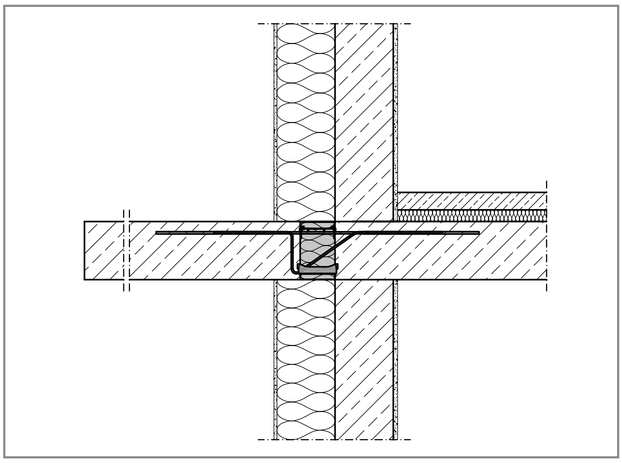
The equivalent thermal conductivity λ_{eq} is the overall thermal conductivity of all components of the Schöck Isokorb® and is - at the same insulting element thickness - a measure for the thermal insulating effect of the connection. The smaller λ_{eq}, the higher the thermal insulation of the balcony connection. λ_{eq} values are determined through detailed thermal bridge calculations. Since each product has an individual geometry and placement specification, each Schöck Isokorb® has an individual number.

For the purpose of comparison of load bearing thermally insulating elements of varying element thickness, the equivalent resistance to heat transmission R_{eq} is used instead of λ_{eq} since it considers the insulating element's thickness in addition to the equivalent thermal conductivity λ_{eq}. The larger R_{eq}, the better thermal insulation effect. R_{eq} is calculated from the equivalent thermal conductivity λ_{eq} and the insulating element thickness as following:

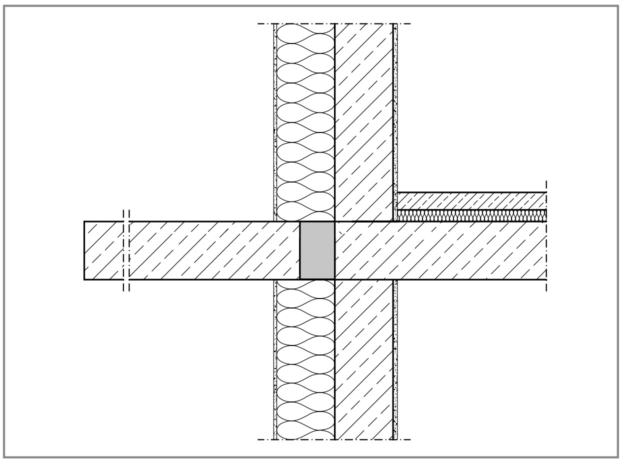
$$R_{eq} = \frac{d}{\lambda_{eq}}$$

Detailed thermal bridge calculation

Where a detailed thermal bridge calculations is to be provided for the determination of ψ or f_{Rsi} values, the λ_{eq} value can be used in modelling of the connection details. For this purpose, a homogenous rectangle of the same dimensions of the Schöck Isokorb® insulting element is placed into the model in its position and the equivalent thermal conductivity λ_{eq} assigned. Refer to figure. In this way, the building physics characteristic values of a design can be simply calculated.



Representation of a sectional drawing with detailed Schöck Isokorb® model



Representation of a sectional drawing with substitute insulating element

The calculation methodology to determine λ_{eq} was validated based on the European Assessment Document - EAD for load bearing thermal insulating elements and - based on this - for Schöck Isokorb® in a European Technical Assessment - ETA.

It is possible to do the calculations using commercially available thermal bridge software by means of the thermal boundary conditions according to BS EN ISO 6946. In doing so, surface temperatures Θ_{si} and the resulting temperature factor f_{Rsi} can be calculated in addition to the heat loss through the thermal bridge (ψ value).

Difference between ψ-value and λ_{eq}

The equivalent thermal conductivity λ_{eq} of the insulating element of the Schöck Isokorb® is a measure for the the heat insulating effect of the element, while the ψ-value represents a measure for the heat insulationof the complete "balcony" structure. The ψ-value changes with construction even if the connection element remains unchanged.

Conversely, the ψ-value with firmly specified design is dependent on the equivalent thermal conductivity λ_{eq} of the connection element: The smaller λ_{eq}, the smaller the ψ-value (the higher the minimum surface temperature).

Requirements

Condensation control and temperature factor

Building Regulations Part L includes the requirement that minimum internal surface temperatures should be such that condensation risk is minimized and mould growth avoided.
Approved Document L1A (L2A for non-residential buildings) cites the BRE Information Paper IP1/06 (Assessing the effects of thermal bridging at junctions and around openings) which includes some limiting values for f_{Rsi}:

Type of building	Minimum f_{Rsi}
Dwellings, residential buildings, schools	0.75
Offices, retail premises	0.50
Sports halls, kitchens, canteens, buildings heated with unflued gas heaters	0.80

Details using Schöck thermal breaks show temperature factors far in excess of Part L requirements in all cases. Temperature factors can be calculated by Schöck on request to provide bespoke details that verify code compliance.

Heat Losses

To pass Building Control requirements in England it is necessary to demonstrate compliance with Building Regulations. The lastest version of the Building Regulations Part L (2013) and associated guidance document for residential construction Approved Document L1A (ADL1A) require that thermal bridging be included in the fabric heat loss calculations.

The government Standard Assessment Procedure (SAP 2012) is the simple energy use and carbon emissions model used to provide evidence that the carbon emissions target has been achieved. The SAP calculation includes the term H_{TB} (heat loss due to thermal bridging) which is calculated or estimated as below:

a) The sum of all linear thermal transmittances (ψ) · length of detail (L)

$$H_{TB} = \sum(L \cdot \psi)$$

or, if no linear thermal transmittances are known:

b) Using the factor y = 0.15 in the equation below:

$$H_{TB} = y \cdot \sum A_{exp} \qquad \text{(where } A_{exp} = \text{total exposed fabric area)}$$

Linear thermal transmittance values (ψ) used in (a) can be a combination of:

- Approved Design Details if used (in 'Approved' column of SAP Appendix K Table K1)
- Uncalculated details (in 'Default' column of SAP Appendix K Table K1)
- Modelled details, in which numerical modelling has been carried out by a person of suitable experience and expertise.

Method (a) is always preferable as it avoids the penalty imposed by (b) which can double the overall calculated heat loss in a well-insulated construction. A similar approach is taken for non-residential buildings in Part L2A, in which the Simplified Bilding Energy Model (SBEM) is used in place of SAP.

One off calculations of ψ can be carried out on request for all details using Schöck thermal breaks to obtain the optimal solution.