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# Avoidance of Thermal Bridging in Steel Construction

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# FOREWORD

Energy efficiency is becoming an increasingly important parameter in the design of buildings. The thermal insulation provided by the building envelope is key to energy efficiency but thermal bridges - weak spots in the insulation - lead to local heat losses that reduce the efficiency.

The information presented in this publication illustrates how thermal bridging occurs in a number of design situations. It describes the results of thermal modelling analyses of typical interface details used in steel construction. The details described have not been designed to optimise thermal performance and in practice further thermal modelling analyses would be needed to identify the modifications required to improve the thermal performance of the details.

The information may be used as general guidance on how to minimise thermal bridging in steel construction.

The publication was prepared by Andrew Way of The Steel Construction Institute and Chris Kendrick of Oxford Brookes University with assistance from Mark Lawson and Michael Sansom of The Steel Construction Institute. The thermal modelling was carried out by Oxford Brookes University.

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# Contents

# SUMMARY

Thermal bridges in the thermal insulation of envelopes occur in all forms of building construction and should be minimised to reduce local heat losses. This publication provides information and guidance on how thermal bridging can be minimised in steel construction.

The report provides an introduction to thermal bridging, an explanation of the consequences of thermal bridging (local heat loss and the possibility of condensation), and describes how these effects are considered in building regulations. Different methods for minimising thermal bridges in steel construction are described and examples to demonstrate the different methods are presented. The examples include presentations of the results of thermal modelling of typical interface details that cause thermal bridges in steel construction. Details of beams penetrating an insulated building envelope, balcony support details and brickwork support systems are included.

# 1 INTRODUCTION

## 1.1 Thermal performance

The thermal efficiency of a building envelope is a function of the thermal performance of the planar elements (e.g. wall, roofs, windows) and the local heat losses that can occur around the planar elements and where the planar elements are penetrated by building components. These local heat losses are the result of areas of the envelope where the thermal insulation is impaired. These areas of impaired thermal insulation are known as 'thermal bridges' or 'cold bridges'.

Revisions to the Building Regulations for England and Wales (see Section 1.5) have emphasised the importance of the thermal efficiency of building envelopes, including limiting heat losses through thermal bridges.

The parameter used to express the thermal performance of a planar element is its U-value. The U-value is the overall coefficient of heat transmittance, which gives a measure of the heat flow through materials. Lower U-values equate to higher levels of thermal insulation. U-values are expressed in units of Watts per square metre Kelvin ($W/m^2K$).

As part of a thermal assessment of the building envelope, it is recognised that local heat losses due to penetrations or similar local effects have to be calculated and where necessary minimised, so that the thermal efficiency of the building envelope is within acceptable limits.

## 1.2 Thermal bridging

Thermal bridges occur where the insulation layer is penetrated by a material with a relatively high thermal conductivity and at interfaces between building elements where there is a discontinuity in the insulation. Thermal bridges result in local heat losses, which mean more energy is required to maintain the internal temperature of the building and lower internal surface temperatures around the thermal bridge. Cold surface temperatures can cause condensation which may lead to mould growth.

Local heat losses caused by thermal bridges become relatively more important, as the thermal performance (i.e. U-values) of the planar elements of the building envelope are improved.

Thermal bridges in building envelopes may be caused by:

- Geometry (e.g. at corners which provide additional heat flow paths)
- Building envelope interfaces (e.g. window sills, jambs and headers)
- Structural interfaces (e.g. floor to wall junctions, eaves)
- Penetration of the building envelope (e.g. balcony supports, fixings and structural elements)
- Structural considerations (e.g. lintels, cladding supports,)
- Poor construction practice (e.g. gaps in insulation, debris in wall cavity).

Other more regular local thermal bridges, such as wall ties, wall studs and mortar joints are accounted for in the U-value calculation for the planar elements. Therefore, heat losses through these regular local thermal bridges do not need to be considered in addition to the heat loss through the planar element.

Heat will find the path of least resistance from the internal (warm) space to the outside (cold) space. Heat will 'short circuit' through an element which has a much higher conductivity than surrounding material. Thermal bridges can be identified using thermal imaging cameras. The thermal bridges will appear as areas of higher temperature when viewed from the exterior of a building. This is shown in Figure 1.1 where higher temperatures (i.e. thermal bridges) around the door, window and ground slab can be seen.

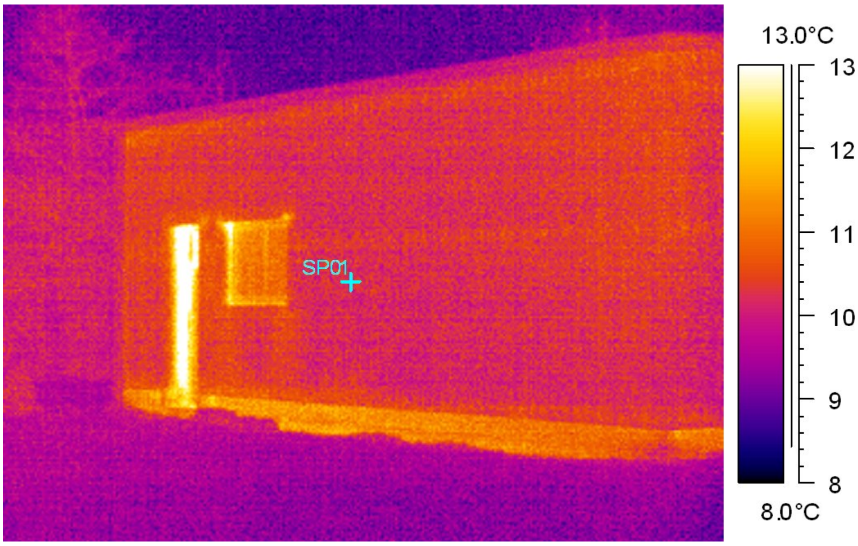



**Figure 1.1** *Thermal image of a small industrial building*

This publication considers the potential sources of thermal bridging in steel framed buildings and how these effects may be calculated.

## 1.3 Steel and thermal bridging

Steel has a high thermal conductivity ($\lambda$) compared with many other construction materials (see Table 1.1). The high thermal conductivity means that steel construction systems, both the structural frame and cladding, must be carefully designed to minimise unwanted heat flows. For example, built-up cladding and composite (sandwich) cladding panels with steel skins are designed to keep thermal bridging to a minimum by ensuring that steel elements are not continuous through the cladding e.g. for a built up cladding system as shown in Figure 1.2, a thermal break is provided beneath the bracket.

**Table 1.1** *Thermal conductivity of common construction materials*

| Material | Thermal conductivity, $\lambda$ (W/mK) |
|---|---|
| Steel | 45 to 50 |
| Stainless steel | 15 to 17 |
| In-situ normal weight concrete | 1.7 to 2.2 |
| Brickwork | 0.6 to 0.8 |
| Gypsum-based board | 0.16 to 0.22 |
| Plywood | 0.12 to 0.15 |
| Mineral wool insulation | 0.03 to 0.04 |
| Closed cell insulation | 0.02 to 0.03 |

Source: CIBSE Guide A: Environmental Design, CIBSE[1]

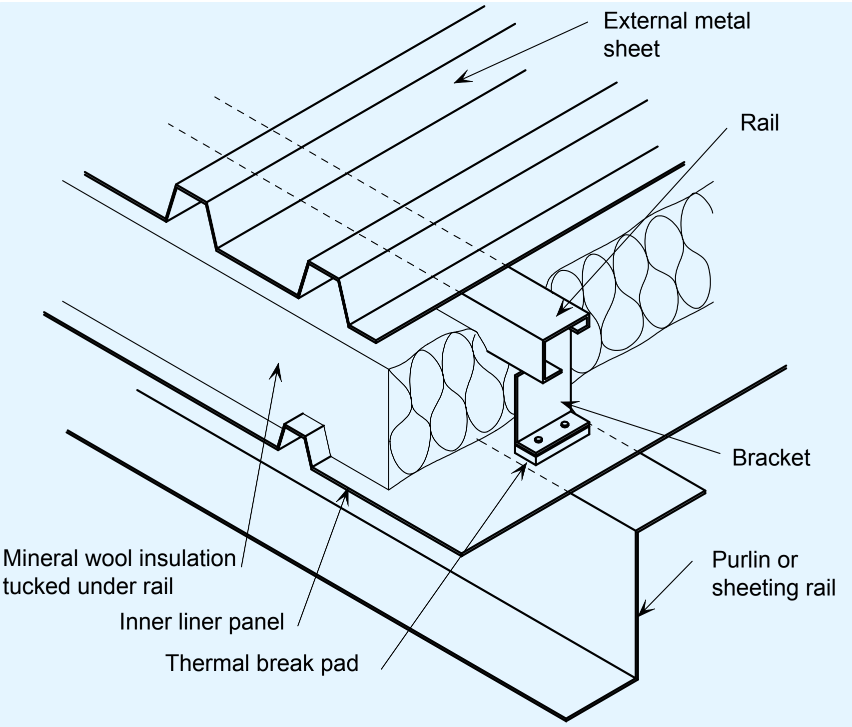



**Figure 1.2** *Example of a cladding detail to avoid thermal bridges*

For some buildings there may be situations where structural steel elements penetrate the insulated envelope (e.g. canopies and roof members) or be fixed to other steel components, such as balcony brackets and brick support units. These areas require careful consideration.

There are three ways of reducing thermal bridging in steel construction:

(a) Eliminate the thermal bridge by keeping the steelwork within the insulated envelope

(b) Locally insulate any steelwork that penetrates the envelope

(c) Reduce the thermal transmittance of the thermal bridge by using thermal breaks, changing the detailing or by including alternative materials.

These methods are considered in detail in Section 2.

## 1.4 Heat loss

The heat loss through a linear thermal bridge (i.e. linear along the envelope), such as a brickwork support angle, is defined by its linear thermal transmittance (termed $\Psi$-value or psi value). Linear thermal transmittance is rate of heat flow per degree temperature difference per unit length of the thermal bridge. The units for $\Psi$-values are Watts per metre Kelvin (W/mK).

Repeating thermal bridges, such as wall studs or brick ties, are normally included in the U-value but non-repeating thermal bridges, such as floor junctions, window sills and ridges, form additional heat transfer paths that are not included in the U-value. These can be accounted for by the linear thermal transmittance ($\Psi$-value) for each thermal bridge.

The total fabric conduction heat loss (per Kelvin) is then given by:

$$\Sigma(\Psi.L) + \Sigma(U.A)$$

where:

- $\Psi$ is the linear thermal transmittance (W/mK)
- $L$ is the length of the thermal bridge (m)
- $U$ is the U-value of the planar element (W/m$^2$K)
- $A$ is the area of the planar element (m$^2$).

$\Psi$-values for thermal bridges can be obtained from two- and three-dimensional thermal conduction modelling or they may be available from product manufacturers/system suppliers. For building products and systems, such as composite panels and built-up steel cladding, manufacturers can usually provide these $\Psi$-values. Generic details and $\Psi$-values for metal clad buildings are available from MCRMA[2] and EPIC[3].

### *Example calculation*

Consider a wall 7.2 m high and 5 m wide with a basic U-value of 0.22 W/m$^2$K. The wall has two horizontal linear thermal bridges, at 3.6 m vertical spacing. The $\Psi$-value of the thermal bridge is 0.30 W/mK.

The total fabric conduction heat loss is given by:

$$\begin{aligned}\Sigma(\Psi.L) + \Sigma(U.A) &= (0.30 \times 2 \times 5) + (0.22 \times 5 \times 7.2)\\ &= 3.00 + 7.92\\ &= 10.92 \text{ W/K}\end{aligned}$$

This calculation shows that the thermal bridge theoretically results in 38% of additional heat loss compared to the wall with no thermal bridges.

## 1.5 Building regulations

Thermal bridging has become more of an issue following the introduction of the 2006 revision of Part L of the Building Regulations for England and Wales. Guidance on meeting Part L of the Building Regulations is provided in Approved Documents L1A, L1B, L2A and L2B[4].

One of the principal criteria given in Approved Documents L1 and L2 is concerned with the predicted emission rate of carbon dioxide ($CO_2$). The predicted emission rate of $CO_2$ from a building should not exceed the target $CO_2$ emission rate, TER. The predicted emission rate of $CO_2$ is based on the calculated annual energy requirements for space heating, water heating and lighting, less the emissions saved by renewable energy generation technologies. For dwellings, the TER is equal to 80% of the emissions from a notional gas heated dwelling of the same size and shape, compliant with the 2002 version of the Building Regulations. For non-domestic buildings which are air-conditioned or heated and mechanically ventilated, the TER is equal to 72% of emissions from a notional 2002 Building Regulations compliant building and 77% from a heated and naturally ventilated building.

Thermal bridging is included in the calculations for heat loss from the building envelope. Guidelines are given in BRE IP1/06[7], which is referenced in the Building Regulations. It is thus valuable to understand the extent of thermal bridging caused by typical building details, and how this is affected by changes in dimensions.

Part L requires that the building fabric should be constructed such that there are no significant thermal bridges at the joints between elements; the designer should ideally aim for a thermal bridge free design. However, it is not generally possible to avoid thermal bridges completely, but it is possible to limit their detrimental effect by appropriate insulation techniques.

Thermal bridges become more significant as a proportion of total heat loss, when the heat transmittance or U-value of the overall envelope is designed to achieve a higher thermal performance. Energy performance requirements are expected to become more stringent as the Building Regulations are revised and as The Code for Sustainable Homes[5] becomes compulsory. Therefore, the effect of thermal bridges will become more significant in the thermal performance of building envelopes.

## 1.6 Methodologies for calculating energy performance

In the UK, SAP 2005 and SBEM are the two *National Calculation Methodologies* for calculating the energy performance of a building taken as a whole, including services. Government approved implementation software is available that calculates the predicted and target $CO_2$ emissions rates. SAP 2005 is the Standard Assessment Procedure for dwellings and SBEM is the Simplified Building Energy Model for buildings other than dwellings. Both SAP 2005 and SBEM require the designer to have knowledge about the thermal bridges because heat losses through thermal bridges must be included in the calculations of predicted rates of $CO_2$ emissions.

For dwellings, *Accredited Construction Details* may be used. *Accredited Construction Details* are a range of published details that have been designed to have linear thermal transmittance values that do not exceed the values given in Reference 7.

*Accredited Construction Details* for England and Wales are available from the Technical Guidance section for Part L of The Building Regulations from the UK Government's Planning Portal website, *www.planningportal.gov.uk*.

*Accredited Construction Details* for Scotland are available from the Technical Handbook section of the Scottish Building Standards Agency website, *www.sbsa.gov.uk*.

The *Accredited Construction Details* for steel construction all relate to light steel. Therefore, they do not provide significant assistance for detailing potential thermal bridges in hot-rolled steel frames.

The maximum $\Psi$-values for *Accredited Construction Details* for various thermal bridge junctions are given in Reference 7 and selected values are reproduced in Table 1.2.

**Table 1.2** *Maximum $\Psi$-values for Accredited Construction Details*

| Junction | Linear Thermal Transmittance $\Psi$-Value (W/mK) |
|---|---|
| Steel lintel with perforated steel base plate | 0.50 |
| Sill | 0.04 |
| Jamb | 0.05 |
| Ground floor | 0.16 |
| Intermediate floor between dwellings [(a)] | 0.14 |
| Balcony within a dwelling [(b)] | 0.00 |
| Balcony between dwellings [(a, b)] | 0.04 |
| Gable (insulation at ceiling level) | 0.24 |
| Eaves (insulation at ceiling level) | 0.06 |
| Corner | 0.09 |

Notes:

a) For these junctions, half of the $\Psi$-value is applied to each dwelling.

b) This is an externally supported balcony (the balcony slab is not a continuation of the floor slab) where the wall insulation is continuous and not bridged by the balcony slab.

For SAP 2005 calculations, the heat loss through thermal bridges ($H_{TB}$) may be calculated by $\Sigma(\Psi.L)$ as shown in Section 1.4. Or, if $\Psi$-values are not known individually, approximate values may be used, as shown below.

$$H_{TB} = y \, \Sigma A$$

where:

$y$ = 0.08 if *Accredited Construction Details* are used

$y$ = 0.15 if non-accredited construction details are used

$\Sigma A$ is the external surface area of the dwelling.

Thermal bridging can thus add a significant percentage to the overall fabric heat loss.

For smaller projects, it is better to ensure *Accredited Construction Details* are used, if possible. However, for larger projects, it may be economic to calculate the thermal bridge losses separately.

### *SAP Comparison Example*

This example illustrates the effect on the SAP rating of using three different categories of junction detail. The three options used are:

- Option 1: *Accredited Construction Details* ($H_{TB}$ = 0.08 × total exposed surface area)
- Option 2: Non-accredited details with unknown $\Psi$-values ($H_{TB}$ = 0.15 × total exposed surface area)
- Option 3: Non-accredited details with known $\Psi$-values ($H_{TB} = \Sigma\{\Psi \times$ length of thermal bridge$\}$).

The multi-storey residential building shown in Figure 1.3, which has a *Slimdek* floor construction, is used for the example.


**Figure 1.3** *Apartments used for SAP comparison*

For Option 3, the linear thermal transmittances ($\Psi$-values) were calculated using thermal modelling software. The $\Psi$-values obtained are summarised in Table 1.3. The $\Psi$-values were then multiplied by the length of each thermal bridge to give a total heat loss for thermal bridging ($H_{TB}$) for each apartment. Three different types of apartments were used for the comparison (top floor corner apartment, mid-floor corner apartment and mid-floor non-corner apartment); these are highlighted in Figure 1.3. In the SAP analysis, the floor area of the apartments was 7 m$^2$ for corner apartments and 7 m$^2$ for non-corner apartments, the floor to ceiling height was 3.1 m and the heating was provided by gas condensing boilers (91% efficiency), radiators and hot water storage tanks.

**Table 1.3** *Ψ-values for typical apartment block in Figure 1.3*

| Junction | Linear Thermal Transmittance Ψ-Value (W/mK) |
|---|---|
| Roof with external wall junction | 0.468 |
| External wall corner | 0.048 |
| Window sill | 0.093 |
| Window jamb | 0.053 |
| Window header (lintel) | 0.314 |
| Balcony floor | 0.565 |
| Floor between dwellings with external wall | 0.280 |

The steel frames comprise RHS edge beam sections supporting *Slimdek* floors, with brick-clad walls supported by masonry support angles and brackets bolted to the RHS edge beam on each floor.

U-values of the basic elements were taken as:

- Walls = 0.30 $W/m^2K$
- Roof = 0.21 $W/m^2K$
- Windows = 2.20 $W/m^2K$

The results of this example are shown in Table 1.4. The target emission rates for dwellings are calculated using the procedures described in Approved Document L1A[4].

**Table 1.4** *Carbon dioxide emissions and SAP ratings for apartments*

| Apartment Location | Target Emissions Rate | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|---|
| | | Dwelling Emissions Rate | SAP Rating | Dwelling Emissions Rate | SAP Rating | Dwelling Emissions Rate | SAP Rating |
| Top floor corner apartment | 23.53 | 21.42 | 83 | 22.76 | 82 | 21.81 | 83 |
| Mid floor corner apartment | 20.65 | 18.55 | 85 | 18.99 | 85 | 19.03 | 85 |
| Mid floor non-corner apartment | 19.65 | 17.64 | 85 | 18.1 | 85 | 18.34 | 85 |

Note: Emission rates are measured in $kg/CO_2/m^2/yr$

From Table 1.4, it can be seen that all the junction detail options for all the apartment locations comply with Part L because the Dwelling $CO_2$ Emission Rates are less than the Target $CO_2$ Emission Rate. The example demonstrates that the approximations for thermal bridging in SAP are in line with modelled results, and that there is little advantage to be gained from modelling individual details for this building. In this example, the difference between using *Accredited Construction Details* and non-accredited construction details on the Dwelling Emission Rate is between 3% and 6%.

## 1.7 Control of condensation

Although heat loss is a very important effect of thermal bridging, the more potentially serious aspect as far as building occupiers are concerned arises from the occurrence of low internal surface temperatures in the region of the thermal bridge. Low surface temperatures can lead to surface condensation if they are below the dew point of the air. For non-absorbent surfaces, condensation can cause unsightly collection of moisture and dripping/pooling on surfaces beneath. For absorbent materials such as insulation products or plasterboard, interstitial condensation can occur, leading to loss of thermal performance and/or structural integrity and mould growth. The local relative humidity need only be sustained at above 80% for mould growth to accelerate.

BS 5250 *Code of Practice for control of condensation in buildings*[6], describes the causes and effects of surface and interstitial condensation in buildings and gives recommendations for their control. Further information on condensation due to thermal bridges is provided in BRE Information Paper 1/06[7].

An indicator of condensation risk is provided by the temperature factor $f_{Rsi}$. This factor is given by the following equation in the BRE paper:

$$f_{Rsi} = (t_{si} - t_{ao})/(t_{ai} - t_{ao})$$

where:

$t_{si}$ is internal surface temperature (from thermal modelling)

$t_{ao}$ is external air temperature

$t_{ai}$ is internal air temperature.

Minimum recommended values of $f_{Rsi}$, termed critical temperature factors $f_{CRsi}$, are given in Reference 7 and are reproduced in Table 1.5. The critical temperature factors depend upon the building use and the consequent internal relative humidity of the building. The higher the likely internal humidity, the higher the critical temperature factor will be to eliminate the likelihood of condensation.

**Table 1.5** *Recommended critical temperature factors $f_{CRsi}$*

| Type of building | $f_{CRsi}$ |
|---|---|
| Storage buildings | 0.30 |
| Offices, retail premises | 0.50 |
| Dwellings; residential buildings; schools | 0.75 |
| Sports halls, kitchens, canteens | 0.80 |
| Swimming pools, laundries, breweries | 0.90 |

Source: BRE IP1/06 [Reference 7]

# 2 MINIMISING THERMAL BRIDGING IN STEEL CONSTRUCTION

Steel is a good conductor of heat and therefore poses particular challenges for minimising thermal bridging. However, there are effective methods of detailing steel components within, or penetrating, building envelopes without causing high heat loss and condensation risk.

## 2.1 Eliminate thermal bridging

Keeping the steelwork within the insulated envelope of the building is the preferred means to eliminate a thermal bridge. However, there will be situations where the steelwork has been detailed to penetrate the envelope for a reason.

An example of how to eliminate a thermal bridge or at the very least minimise the extent of thermal bridging is shown by the comparison in Figure 2.1. Figure 2.1(a) shows balconies supported from the structural frame of the building; this requires significant structural connections thereby creating thermal bridges. Figure 2.1(b) shows an alternative, where balconies are supported independently; this requires considerably less connection to the building and the thermal bridging is significantly reduced.

(a) Structure supported balconies

(b) Independently supported balconies

**Figure 2.1** *Balcony support options*

## 2.2 Local insulation

Where a steel member penetrates the insulated envelope of a building, insulation may be provided around the element to lengthen the heat flow path, thereby, reducing heat losses and raising the internal surface temperature of the element. Additional insulation can be applied on either the internal or external side of the building envelope. Figure 2.2 shows a beam with local internally applied insulation. The amount of insulation required in terms of thickness and length along the member will depend on the particular circumstance and can be determined with the aid of thermal modelling. Factors to be considered include: the size of the member, the U-value of the building envelope and the internal conditions of the building (temperature and humidity).

A typical solution is to insulate the steel member for a length of 1.2 m with 50 mm thick rigid insulation. Conveniently, most rigid insulation boards are supplied 1.2 m wide. Placing insulation on the internal side of the beam will reduce the temperature of the insulated part of the beam. Therefore, it is essential that a vapour control layer is applied around the outside of the insulation to prevent condensation. Boards with factory applied facings can be used to provide vapour control. Specialist adhesive tapes can be used to seal joints and edges.

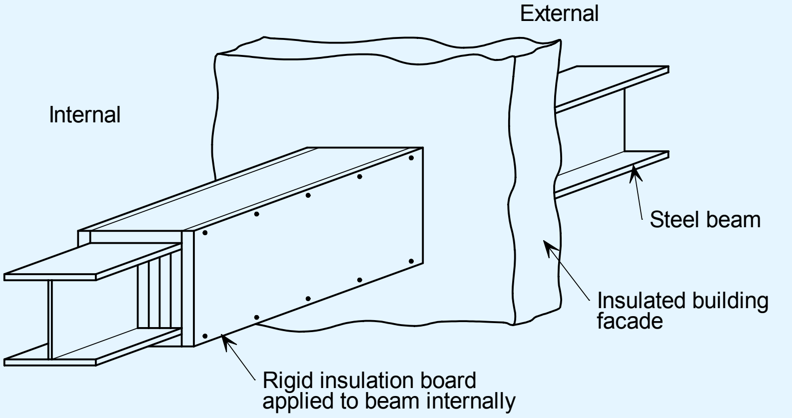



**Figure 2.2** *Locally insulated beam*

An example of a member that is locally insulated externally to the building envelope is described in Section 3.1.1.

## 2.3 Reducing thermal transmittance

The thermal transmittance of a thermal bridge can be reduced by using thermal breaks, changing the detailing or by including alternative materials.

### 2.3.1 Thermal breaks

Thermal breaks may be provided by inserting a material with a low thermal conductivity between elements with higher thermal conductivities, as illustrated in Figure 2.3. Reducing the cross-sectional area of an element can also be used to reduce its thermal transmittance where it bridges an insulated building envelope.

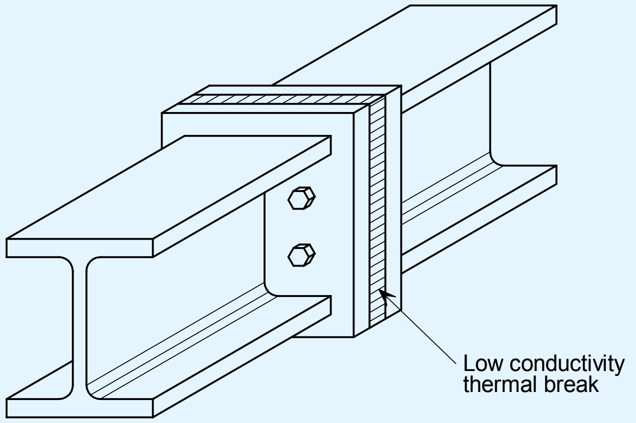



**Figure 2.3** *Thermal break between two steel beams*

Thermal breaks are provided in certain manufactured elements, such as metal window frames and composite cladding panels, where the steel skins are separated at junctions by a layer of insulation and in built-up cladding systems where thermal break pads can be provided beneath brackets. Similarly, thermal break pads can be provided behind the brackets of brickwork support systems. The brackets of brickwork support systems are made from stainless steel primarily to resist corrosion but this has the added benefit of reduced thermal bridging because stainless steel has a lower thermal conductivity than carbon steel (see Table 1.1).

Where structural forces are transferred through steel elements that pass through the insulated envelope of a building, such as in balcony connections, brickwork support systems and roof structures, the form of break must be considered carefully. It is vital to ensure that the structural performance remains acceptable. Materials used for thermal breaks will generally be more compressible than steel. Therefore, deflections, as well as strength, should be checked when thermal breaks are used.

Pads and spacers of high thermal resistance can be made from a range of materials such as PTFE, polyethylene and synthetic resin bonded fabric. Proprietary solutions are also available to provide structural thermal breaks (see Section 2.3.4). Examples of thermal breaks using a layer of PTFE bolted between beam end plates and using a proprietary solution bolted between beam end plates are described in Sections 3.1.2 and 3.1.3, respectively.

### 2.3.2 Slotted steel sections

The thermal transmittance of steel stud section can be reduced by forming slots in the web of the section, as shown in Figure 2.4. Overlapping lines of horizontal slots in the web of a light gauge steel C-section can reduce the equivalent thermal conductivity of the section by up to a factor of 10. Slotted plates are also used for the base plate of steel box-section lintels to reduce the heat transfer.

A computer model of the temperature distribution in a slotted light steel plate is shown in Figure 2.5.

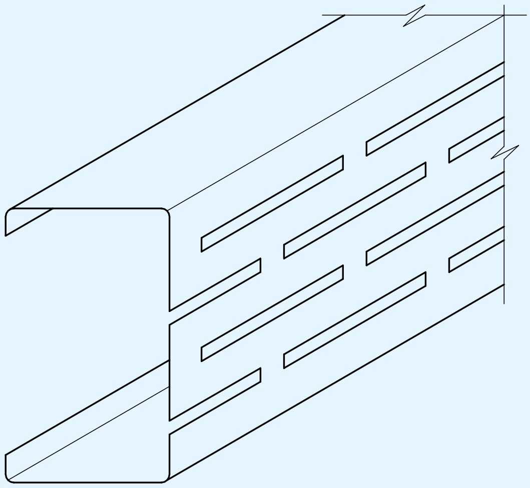


**Figure 2.4** *C section with slotted web*

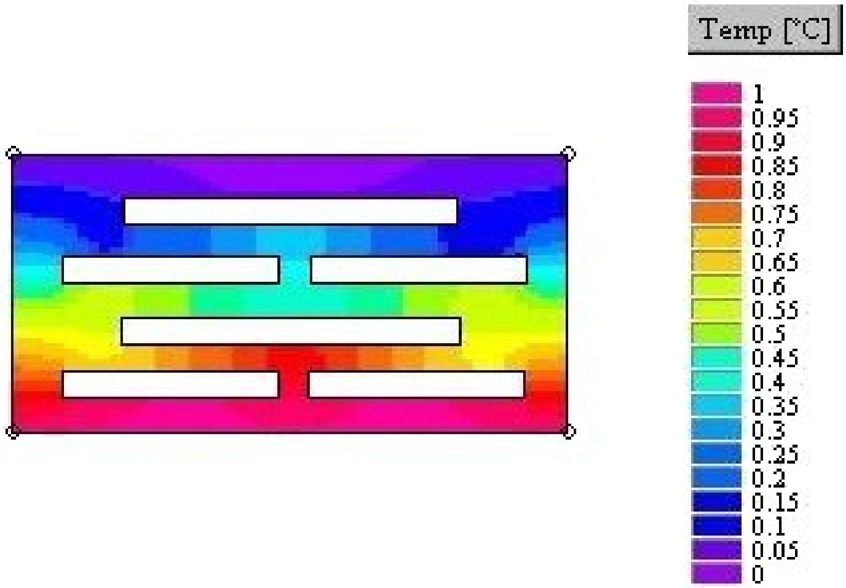



**Figure 2.5** *Temperature distribution through a perforated web*

The slots or perforations increase the length of the heat transfer path considerably, forcing heat to flow on a labyrinthine path instead of straight across (perpendicular to the plane of the temperature differential). Depending upon the pattern employed, slotting can decrease the equivalent thermal conductivity of steel from 50 to a range of 5-10 W/mK. However, there is some loss of structural strength of the member particularly in compression but less so in bending. Slotting the web of light steel wall studs can decrease the walls compressive strength by approximately 30%.

### 2.3.3 Lower-conductivity fixings

The thermal transmittance of a thermal bridge can be reduced by replacing some of the components with components made from materials of a lower thermal conductivity. For example, stainless steel bolts or screws with a thermal conductivity of less than a third of that of carbon steel could be used. The advantage in reduced thermal transmittance of replacing carbon steel bolts with stainless steel bolts is demonstrated in the examples in Section 3.1.2.

Bi-metallic corrosion can occur when dissimilar metals are in contact. For bi-metallic corrosion to occur the metals must be in contact with a common electrolyte e.g. rain or condensation. Bi-metallic corrosion is not an issue if the amount of stainless steel is small compared to the amount of carbon steel or if moisture is not present.

### 2.3.4 Proprietary solutions

Currently, there are relatively few proprietary thermal break solutions available for structural elements. However, thermal break products are available to support balconies, canopies, external staircases and structural members that penetrate the insulated building envelope. These proprietary solutions are designed to have the minimum amount of continuous metal from one side to the other and metal components are encased in an insulating material.

Section 3.1.3 demonstrates the benefits of one such product, which is modelled to assess the local heat loss.

# 3 EXAMPLES

## 3.1 Beams penetrating building envelope

### 3.1.1 Beam with local external insulation

In this example a beam that penetrates the insulated envelope of a building is locally insulated externally to the building envelope to raise the internal surface temperature of the member. The detail is illustrated in Figure 3.1.

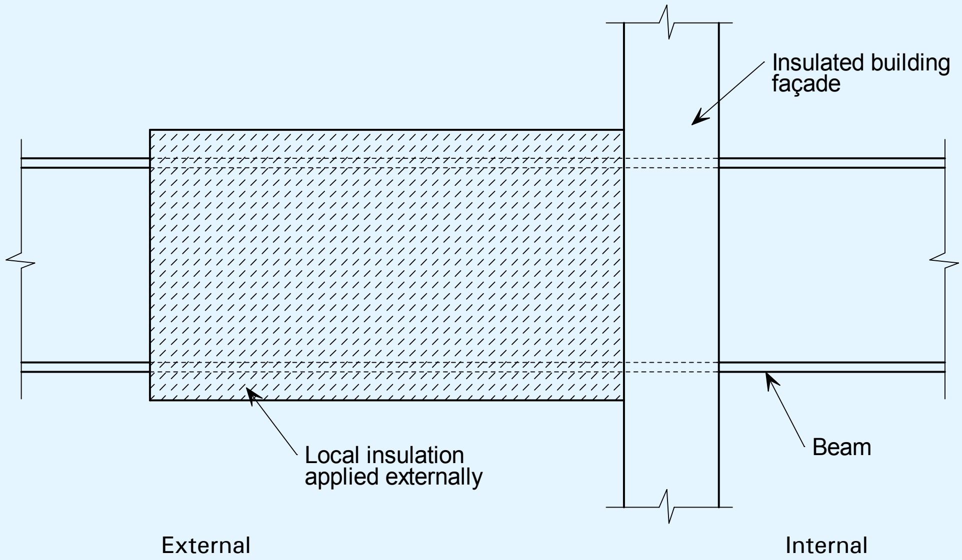



**Figure 3.1** *Locally externally insulated beam*

Thermal conduction analysis was carried out using three dimensional steady-state conduction modelling software. The objective was to determine the lowest surface temperatures on the beam at the interface with the wall line. These internal surface temperatures were compared to the local dew point for the internal conditions, thus assessing the risk of surface condensation.

The same beam without insulation and the beam with two insulation options were modelled. The results of the modelling are shown Table 3.1.

**Table 3.1** *Thermal modelling results for a beam with local insulation*

| Description of model | Minimum internal surface temperature | Temperature factor, $f_{Rsi}$ |
|---|---|---|
| Beam without insulation | 8.90 °C | 0.51 |
| Beam insulated externally for 360 mm | 9.48 °C | 0.54 |
| Beam insulated externally for 1000 mm | 9.66 °C | 0.55 |

Note: This modelling was carried out with an internal air temperature of 17.5 °C and an external temperature of 0 °C.

It can be seen from the results that insulating the beam to a length of 1 m on the external side of the wall only has a marginal effect on the minimum internal surface temperature. The temperature factor for the beam without any insulation is acceptable for storage, office and retail buildings. For other applications, the beam should ideally be boxed in and insulated along its entire exposed length.

### 3.1.2 Beam with a PTFE thermal break

In this example a PTFE thermal break is created in a beam that penetrates the insulated envelope of a building. The PTFE thermal break is created by inserting a layer of PTFE between end plates welded to the beams and then bolted together with four M24 bolts. The thermal conductivity of PTFE is 0.25 W/mK. The designer must ensure the compressive resistance of the thermal break is adequate for structural purposes. A range of products are available with compressive strengths ranging from 200 to 300 $N/mm^2$ and Young's Modulus ranging from 6,000 to 13,000 $N/mm^2$.

The model of the thermal break connection is shown in Figure 3.2. Four variations of the thermal break were modelled; 5 and 10 mm layers of PTFE with either steel or stainless steel bolts. The results of thermal modelling are shown in Table 3.2.

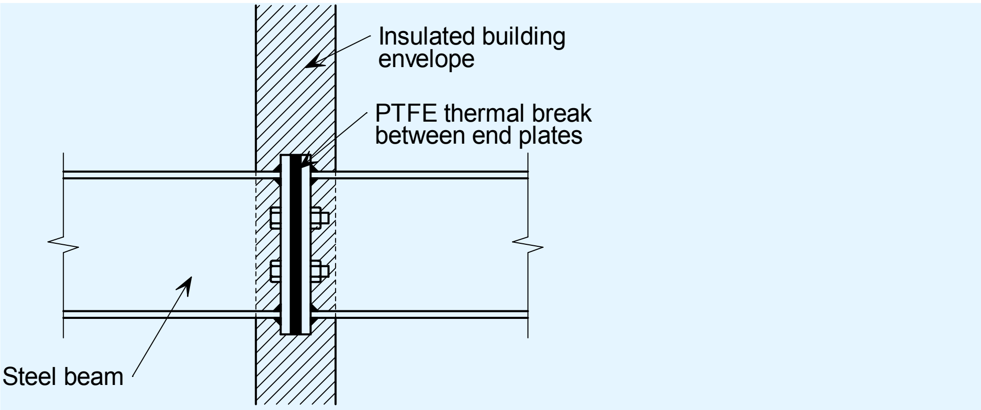



**Figure 3.2** *Beam joined by end plates with PTFE thermal break*

**Table 3.2** *Thermal modelling results for a beam with a PTFE thermal break*

| Description of model | Equivalent thermal conductivity*, $\lambda_{eq}$ W/mK | Minimum internal surface temperature | Temperature factor, $f_{Rsi}$ |
|---|---|---|---|
| Continuous steel beam with no thermal break | 3.48 | 7.5 °C | 0.50 |
| Break by 5 mm PTFE with steel bolts | 7.60 | 5.8 °C | 0.43 |
| Break by 5 mm PTFE with stainless steel bolts | 5.80 | 6.8 °C | 0.47 |
| Break by 10 mm PTFE with steel bolts | 5.70 | 6.9 °C | 0.48 |
| Break by 10 mm PTFE with stainless steel bolts | 3.90 | 8.6 °C | 0.55 |

Note: * Equivalent thermal conductivity over the thickness of the building envelope. This modelling was carried out with an internal air temperature of 20 °C and an external temperature of -5 °C.

It can be seen from the results that the use of end plates can potentially make the thermal bridge worse than the continuous beam. This is because the extra area of contact created by the end plates counteracts the effect of the increased thermal resistance of the PTFE layer. Another contributing factor is that for the continuous beam case, the insulation of the building envelope is formed all round the beam whereas with end plates some of this insulation is removed and replaced by the steel end plates. Only the model with a 10 mm layer of PTFE and stainless steel bolts shows an improvement in the thermal performance over that of a continuous beam penetrating the building envelope. The thermal performance of this type of thermal break detail is sensitive to connection geometry (e.g. beam size, end plate thickness and bolt diameter) and the thickness of the thermal break material.

### 3.1.3 Beam with an *Isokorb* thermal break

In this example an *Isokorb* thermal break unit is used in a beam that penetrates the insulated envelope of a building.

The *Isokorb* thermal break unit, available from Schöck Ltd, is shown in Figure 3.3. The main body of each unit is made from dense polystyrene foam through which pass stainless steel studs with the necessary washers, nuts and plates. The lower part of the unit includes a stainless steel box section to provide compression and shear resistance. The structural capabilities of the Isokorb units are provided in Reference 8.

**Figure 3.3** *Isokorb thermal break*

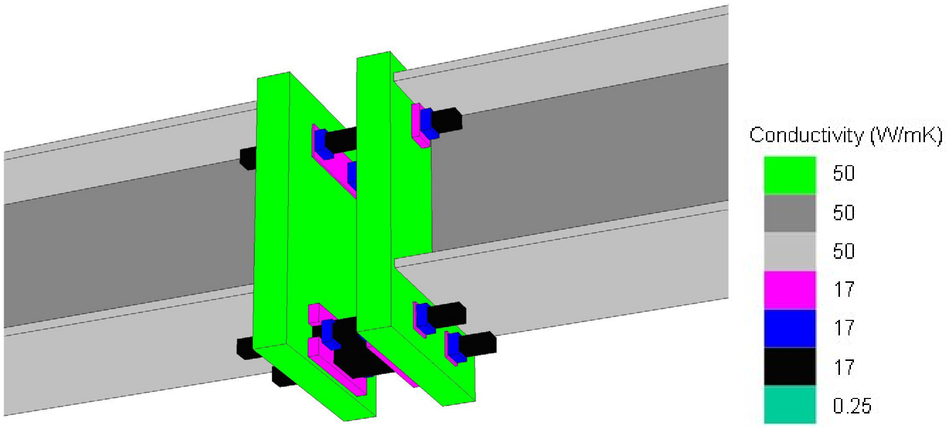
An *Isokorb* unit with M22 bolts was modelled using a three-dimensional steady state thermal conduction analysis program. In the model the building envelope insulation was 80 mm thick, the *Isokorb* unit was 80 mm thick and the beams were bolted to the Isokorb unit using 40 mm thick end plates. The thermal model is shown in Figure 3.4. The results of the thermal modelling, with and without the *Isokorb* unit, are presented in Table 3.3.

**Table 3.3** *Thermal modelling results for a beam with Isokorb*

| Description of model | Thermal bridge heat loss W/K | Minimum internal surface temperature | Temperature factor, $f_{Rsi}$ |
|---|---|---|---|
| Beam with *Isokorb* KST 22 | 0.43 | 15.2 °C | 0.81 |
| Beam without thermal break | 1.0 | 7.5 °C | 0.50 |

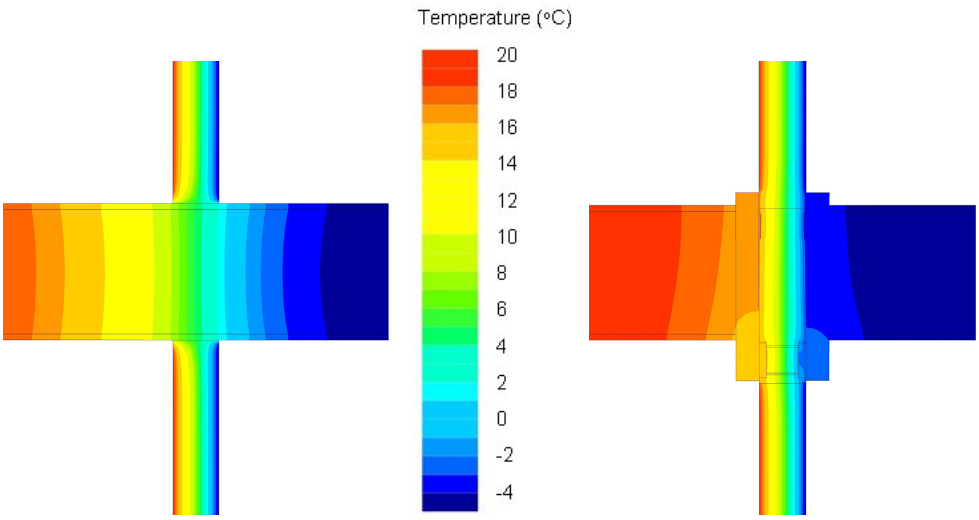
Note: This modelling was carried out with an internal air temperature of 20 °C and an external temperature of -5 °C.

The temperature distributions from the thermal modelling are shown in Figure 3.5. It can be seen from the results that using the *Isokorb* unit significantly improves the thermal performance of the beam penetrating the building envelope. The heat loss is reduced by almost 60% and the temperature factor is improved by over 60%. Without a thermal break the temperature factor is acceptable for non-residential buildings (such as storage, office and retail buildings) but with the *Isokorb* unit the temperature factor becomes more than sufficient for schools, dwellings, sports halls and kitchens.




Note: Insulation omitted for clarity

**Figure 3.4** *Thermal model for an Isokorb unit*




(a) Continuous beam

(b) Beam with thermal isolator

**Figure 3.5** *Temperature distributions*

## 3.2 Balcony attachments

For structure supported balconies as shown in Figure 2.1a), the heat losses at the thermal bridge between the structural frame of the building and the balcony can be significantly reduced by using a proprietary product such as that shown in Figure 3.3. The thermal modelling results presented in Table 3.3 give an indication of the benefit that can be achieved. Manufactures of proprietary products will be able to provide information on their structural and thermal performance. Figure 3.6 shows *Isokorb* units attached to a structural steel frame ready to be connected to external steelwork such as balconies and canopies.

**Figure 3.6** *Isokorb units attached to steel frame*

## 3.3 Brickwork supports

### 3.3.1 Brickwork support fixed to ASB edge beam

In this example the thermal performance of a brickwork support system fixed to a steel ASB edge beam is assessed using thermal modelling.

The bottom flange of an ASB edge beam connected concentrically to a column penetrates into the wall cavity and can interfere with insulation placed in the cavity. Therefore, in this example, the bottom flange is cropped to avoid this problem (see Figure 3.7). The substitution of concrete for fire protection insulation on the outer face of the ASB has implications for thermal performance of the junction. The brickwork support angles are stainless steel angles with stainless steel brackets.

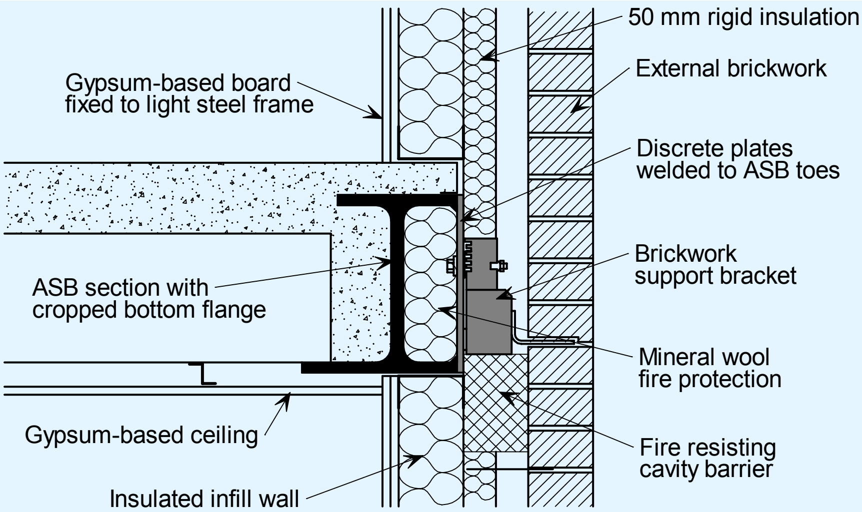



**Figure 3.7** *Typical section through an external wall with a cropped ASB edge beam*

The linear thermal transmittance ($\Psi$-value), the internal surface temperature and the temperature factor ($f_{Rsi}$), were calculated using thermal modelling. Modelling was carried out with and without the mineral insulation on the external web of the ASB and the spacing of the brackets was taken as 400 mm and 1000 mm. The thermal model is shown in Figure 3.8.

The temperature distribution for the detail is shown in Figure 3.9 and the numerical results are presented in Table 3.4.

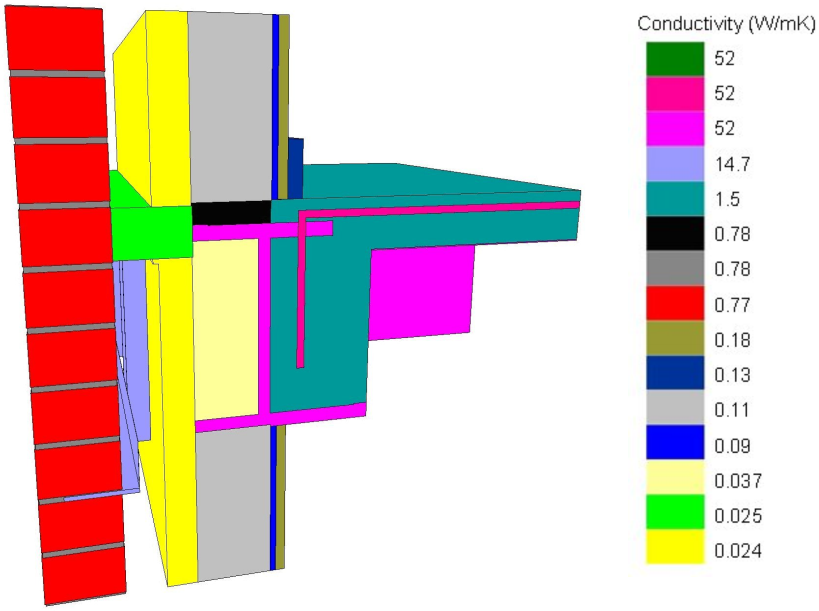



**Figure 3.8** *Model for brickwork support fixed to ASB edge beam (with mineral wool on external web)*

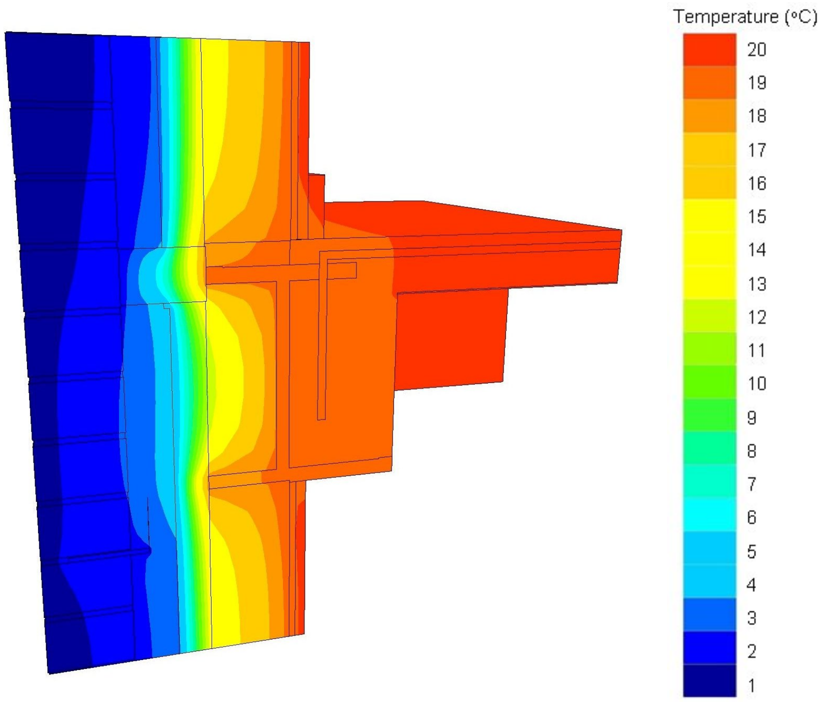



**Figure 3.9** *Temperature distribution for brickwork support fixed to ASB edge beam (with mineral wool on external web)*

**Table 3.4** *Thermal modelling results for brickwork support fixed to ASB edge beam (brackets at 400 mm centres)*

| Description of model | Linear thermal transmittance $\Psi$ W/mK | Minimum internal surface temperature | Temperature factor, $f_{Rsi}$ |
|---|---|---|---|
| With mineral wool infill brackets at 400 mm centres | 0.245 | 18 °C | 0.90 |
| Without mineral wool infill brackets at 400 mm centres | 0.260 | 18 °C | 0.90 |
| With mineral wool infill brackets at 1000 mm centres | 0.126 | 18.5 °C | 0.93 |

Note: This modelling was carried out with an internal air temperature of 20 °C and an external temperature of 0 °C.

From the results it can be seen that:

- Infilling with mineral wool between the flanges of the ASB makes very little difference to the values of $\Psi$ and $f_{Rsi}$, and, hence, the thermal performance.
- The temperature factor is well above the minimum level of 0.75 recommended[7] for dwellings.
- The spacing of the brackets is an important factor in the results. For a bracket spacing of 1000 mm the detail satisfies the $\Psi$-value for intermediate floors between dwellings for *Accredited Construction Details*. However, bracket spacing will usually be dictated by structural requirements.

The following recommendations are made as a result of the analyses:

- No insulation is required for thermal performance on the external face of the ASB (but it may be needed for fire resistance).
- No insulation is needed to the underside of the ASB for thermal performance.
- No special measures are recommended to insulate brickwork support angle brackets from the ASB at bracket spacings greater than about 600 mm.
- For bracket spacings less than 600 mm, thermal spacers between the bracket and the ASB may need to be considered.

Most manufacturers of brickwork support systems offer some form of thermal spacer which can be inserted between the bracket and the steel structure to which they are connected. The thermal spacer is typically HDPE (high density polyethylene) in the order of 3 mm thick. HDPE has a thermal conductivity $\lambda$ of 0.45 to 0.52 W/mK. Some manufacturers are investigating alternative materials for thermal spacers with lower thermal conductivities.

### 3.3.2 Brickwork support fixed to UKB downstand edge beam

In this example the thermal performance of a brickwork support system fixed to a UKB edge beam was assessed using thermal modelling.

The attachment of stainless steel brickwork support angles to a UKB downstand edge beams in composite construction is a common detail, shown in Figure 3.10.

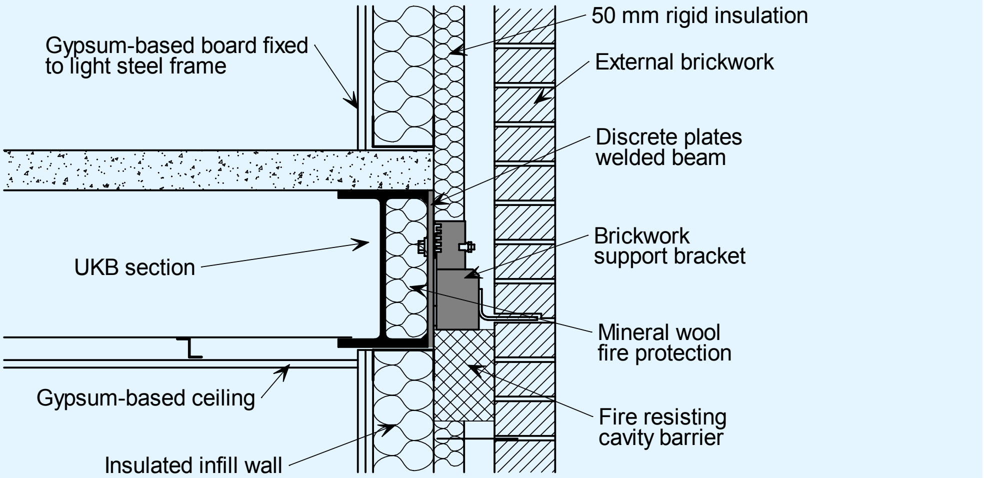



**Figure 3.10** *Section through an external wall with a UKB downstand edge beam*

The thermal model used to determine the thermal performance of this detail is shown in Figure 3.11.

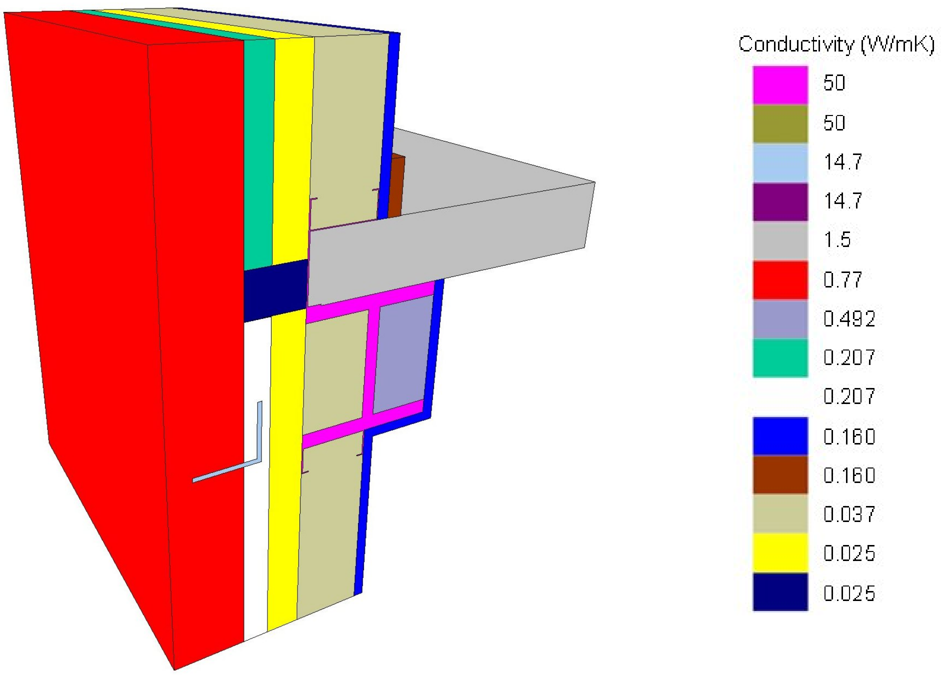



**Figure 3.11** *Thermal model for brickwork supports fixed to UKB downstand edge beam*

The temperature distributions are shown in Figure 3.12 and the results are presented in Table 3.5.

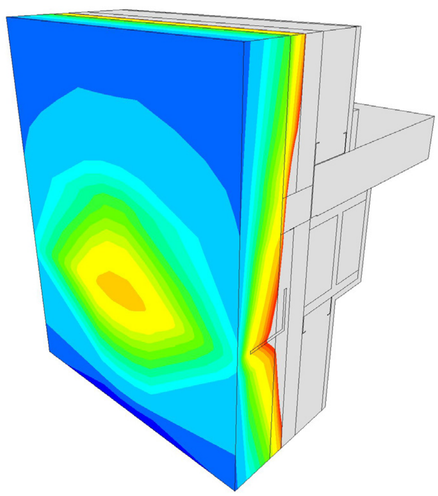
**Table 3.5** *Thermal modelling results for brickwork support fixed to UKB edge beam*

| Description of model | Linear thermal transmittance $\Psi$ W/mK | Minimum internal surface temperature | Temperature factor, $f_{Rsi}$ |
|---|---|---|---|
| Brick supports at 600 mm centres with mineral wool between flanges | 0.341 | 17.7 °C | 0.885 |
| Brick supports at 900 mm centres with mineral wool between flanges | 0.262 | 18.0 °C | 0.901 |
| Brick supports at 600 mm centres without mineral wool between flanges | 0.348 | 17.6 °C | 0.884 |

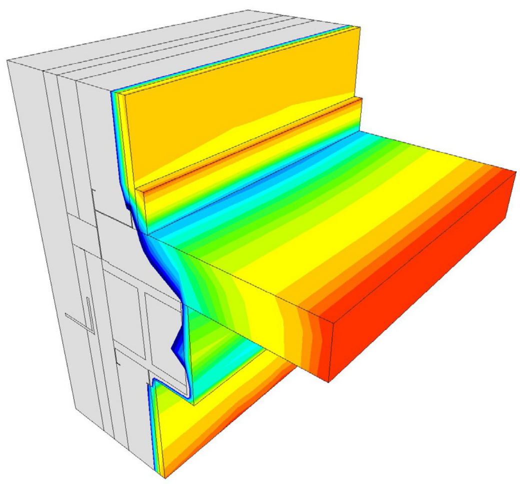
Note: This modelling was carried out with an internal air temperature of 20 °C and an external temperature of 0 °C.

From the results it can be seen that:

- Infilling with mineral wool between the flanges of the UKB makes very little difference to the values of $\Psi$ and $f_{Rsi}$, and, hence, the thermal performance.
- The thermal transmittance is higher than the *Accredited Construction Details* default $\Psi$-value[7] for intermediate floors between dwellings (0.14 W/mK).
- The temperature factor is well above the minimum level of 0.75 recommended[7] for dwellings and 0.5 recommended for offices.
- The bracket spacing is significant for thermal transmittance but not for the temperature factor. Increasing the spacing of the brick support angle fixings by 50% decreases the linear thermal transmittance by 23%.



(a) External



(b) Internal

**Figure 3.12** *Temperature distributions for brickwork supports fixed to UKB edge beam (with mineral wool on external web)*

### 3.3.3 Brickwork support fixed to UKPFC edge beam

In this example, the thermal performance of a brickwork support system fixed to a UKPFC edge beam is assessed using thermal modelling.

A UKPFC edge beam is used with a proprietary floor system and represents a potential linear cold bridge at the building envelope, depending on the location of the insulation and type of cladding used. Figure 3.13 shows a typical detail of a UKPFC edge beam attached at approximately 600 mm centres to a stainless steel masonry support angle.

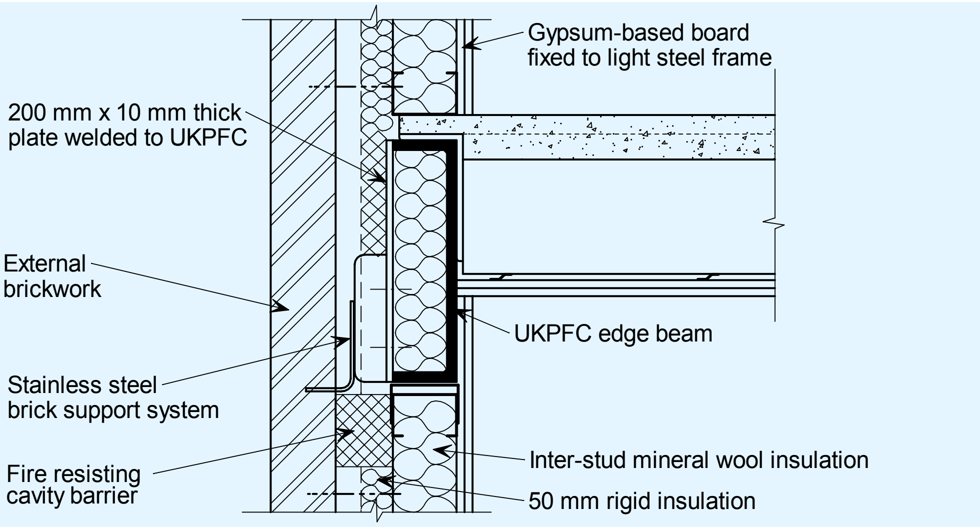



**Figure 3.13** *Section through an external wall with a UKPFC edge beam*

The linear thermal transmittance ($\Psi$-value), the internal surface temperature and the temperature factor ($f_{Rsi}$), were calculated using thermal modelling. The model is shown in Figure 3.14. Fixings to the brickwork support angles are located at 600 or 900 mm spacing along the UKPFC edge beam.

The temperature distributions are shown in Figure 3.15 and the results are presented in Table 3.6.

**Table 3.6** *Results of thermal analyses of UKPFC supporting proprietary floor*

| Description of model | Linear thermal transmittance $\Psi$ W/mK | Minimum internal surface temperature | Temperature factor, $f_{Rsi}$ |
|---|---|---|---|
| Brick supports at 900 mm centres with mineral wool between flanges | 0.273 | 17.5 °C | 0.876 |
| Brick supports at 600 mm centres with mineral wool between flanges | 0.338 | 17.2 °C | 0.860 |
| Brick supports at 600 mm centres with no mineral wool between flanges | 0.343 | 17.1 °C | 0.859 |

Note: This modelling was carried out with an internal air temperature of 20 °C and an external temperature of 0 °C.

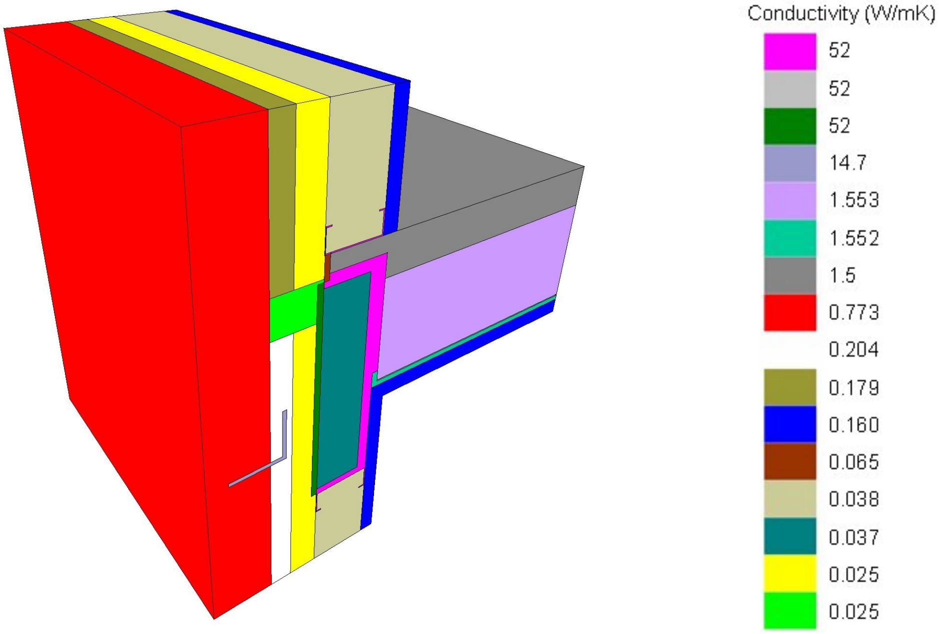
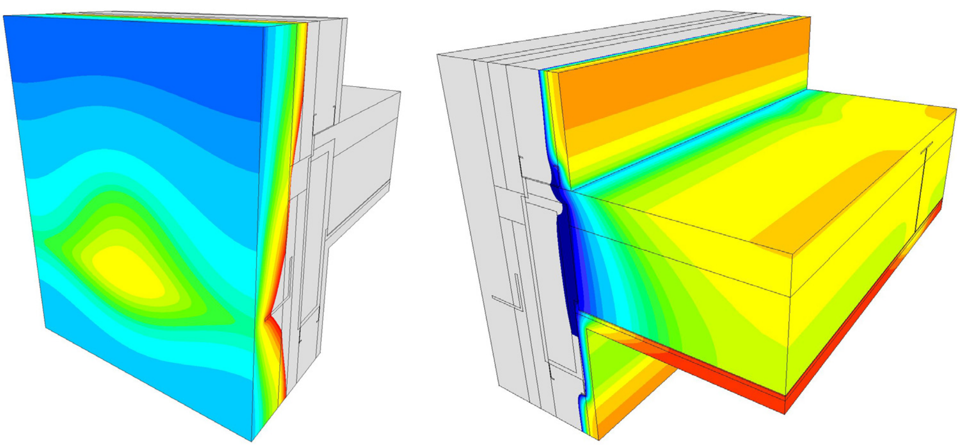



**Figure 3.14** *Thermal model for brickwork supports fixed to UKPFC edge beam (with mineral wool on external web)*

From the results it can be seen that:

- Infilling with mineral wool between the flanges of the UKPFC makes very little difference to the values of $\Psi$ and $f_{Rsi}$, and, hence, the thermal performance.
- The thermal transmittance is higher than the *Accredited Construction Details* default $\Psi$-value[7] for intermediate floors between dwellings (0.14 W/mK).
- The temperature factor is well above the minimum level of 0.75 recommended[7] for dwellings and 0.5 recommended for offices.
- The bracket spacing is significant for thermal transmittance but not for the temperature factor. Increasing the spacing of the brick support angle fixings by 50% decreases the linear thermal bridging by 19%.



(a) External (b) Internal

**Figure 3.15** *Temperature distributions for brickwork supports fixed to UKPFC edge beam (with mineral wool on external web)*

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