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Industry CPD

Thermal bridging and structural thermal breaks

This CPD module, sponsored by Farrat, discusses the use of structural thermal breaks to reduce energy transfer and loss between structurally loaded building details.

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1 hour of verifiable CPD

Introduction

In construction, thermal breaks prevent or reduce the flow of thermal energy between elements of a building. Structural thermal breaks help prevent thermal bridges in structurally loaded building details that pass between spaces of differential temperature. The two key reasons for avoiding thermal bridges are:

- to reduce energy loss.
- to mitigate risk of condensation.

This CPD will examine energy transfer and loss, applications and options for structural thermal breaks, materials, thermal and structural performance and fire assessment.

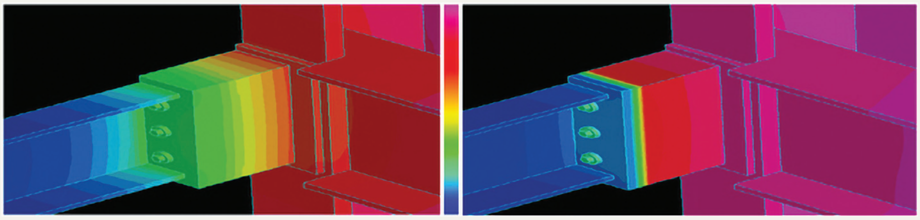

FIGURE 1: Predicted temperature distribution with no thermal break compared to one with thermal break

Why use thermal breaks?

Modern building design and regulation recognises the importance of energy conservation and occupier comfort in all aspects of construction detailing. Developments in material science and advanced manufacturing techniques have led to the use of structural thermal breaks as a way of avoiding thermal bridges in building details that pass between spaces of differential temperature, specifically where the thermal break material needs to perform both in transmitting structural loads as well as preventing thermal movement across the connection.

Poor detailing resulting in thermal bridges **(Figure 1)** can impact severely on the overall performance of a building, in respect of the amount of energy required to heat or cool a space and the cost of that energy both environmentally and monetarily.

Alongside energy loss, thermal bridges in a building fabric can result in condensation and mould growth. This is where the temperature of a room's internal surfaces is sufficiently low for moisture-laden air to reach a dew point temperature and condense and, in some cases, for the propagation of mould spores to occur.

Applications

Thermal breaks can be incorporated into any detail where there is a calculated or perceived risk of a thermal bridge occurring. This is usually:

- in details that occur in building envelopes
- where a significant temperature difference is likely to occur between compartments.

Examples include:

- facade system connections to the primary frame
- brise-soleil and canopies
- roof plantroom columns
- balustrading
- external balconies or staircases
- man-safe systems
- substructure and basement structure elements
- external-to-internal primary building element connections.

The two principal types of structural thermal breaks **(Figure 2)** are:

- mechanical – comprising combinations of structural components and compressive insulating materials used to compensate for the poor thermal performance of the continuous steel elements
- solid-state thermal break plates – used in conventional connections as a structural 'spacer' that also has a high thermal performance.

Energy loss

All materials have a thermal conductivity value. Many materials with high structural performance also have high thermal transmittance, readily conducting heat along members and through connections. These materials must therefore be supplemented or isolated with better-performing materials to achieve an overall satisfactory thermal performance.

To assess the relative thermal performance of combinations of materials in details, empirical calculations can be carried out using the respective conductivity values and figures for the climatic environments into which they are due to be installed.

The simplest of these calculations is for plane elements which are expressed as a 'U' value, where a higher U-value indicates a higher rate of thermal conductivity.

More complex to calculate are linear details which are expressed as a 'Psi' value, while the most complex to calculate are localised elements/point connections, which are expressed as a 'Chi' value. This last value is only able to be attained from complex three-dimensional modelling and is typically where structural thermal breaks are required.

Thermal conductivity values for various materials are presented below:

- Steel: 50.0W/m-k
- Stainless steel: 43.0W/m-k

- →| Concrete: 2.1W/m-k
- →| Farrat TBL: 0.292W/m-k
- →| Wood: 0.22W/m-k
- →| Farrat TBK: 0.187W/m-k
- →| Soft wall insulation: 0.02W/m-k

Heat loss is quantified using three parameters:

- →| plane elements: U-value (W/m²K) – e.g. floors, walls, windows
- →| linear elements: Ψ-value (W/mK) – e.g. interface window/wall opening
- →| localised elements: X-value (W/K) – e.g. structural element penetrating wall.

Condensation

Once a value for thermal transmittance through a detail is established, this can be used to evaluate likely performance in relation to a critical temperature factor. These factors relate to a range of building types and the propensity for moisture to be present in the internal spaces.

The higher the likelihood of there being moist air present, the higher the likelihood of moisture condensing out and causing problems. As such, the higher the risk of condensation, the more important it is to have sound thermal performance of the building fabric to avoid problems associated with condensation, such as mould growth **(Figure 3)** or corrosion, both internally and within the building structure itself.

Material testing

The provision of manufacturing standards allows specifiers to compare performance of differing materials as well as warranting product performance via independent testing. As with all construction products, physical properties and levels of performance can be verified by testing against relevant standards for specific product groups.

As new products are developed, standards are created to assess them. In the case of solid-state structural thermal break plates, there are currently no specific standards; therefore, it is crucial that with these critical components, independent verification of figures and performance is sought via accreditations, such as with a certification from leading association, the BBA.

Material testing takes many forms and is in many cases tailored towards a specific end use. Where there are multiple ways of testing similar physical properties, it is important that the right test is carried out to suit the situation in which the material is used. To this end, material properties that can vary depending on variable use factors – such as compressive strength and thermal transmittance in relation to temperature – need to be assessed correctly.

Materials which appear to have similar values can ultimately perform very differently in real-life conditions.

Table 1 represents the latest results of material testing of Farrat structural thermal breaks, carried out by an approved Nando Accreditation Facility.

The characteristic compressive strength values of Farrat TBF, Farrat TBK and Farrat TBL have been calculated in accordance with BS EN 1990, Annex D. The design resistance is calculated using Equation 1, which is based on BS EN 1990,

↗FIGURE 2: 22 Bishopsgate, London during construction, with Farrat structural thermal break *in situ* (visible at grey end of cellular beam)

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↘FIGURE 3: Mould growth due to excess moisture within domestic building

> **ALONGSIDE ENERGY LOSS, THERMAL BRIDGES IN A BUILDING FABRIC CAN RESULT IN CONDENSATION AND MOULD GROWTH**

TABLE 1: Material properties of Farrat structural thermal breaks (testing carried out by approved Nando Accreditation Facility)

Material properties	Farrat TBF*	Farrat TBK	Farrat TBL
Characteristic compressive strength, f_{ck} (N/mm², MPA)	355	312	89
Design value for compressive strength, f_{cd} (N/mm², MPA)	284	250	70
Compression modulus (N/mm², MPA)	6800	4100	2586
Density (Kg/m²)	2160	1465	1137
Water absorption (%)	0.40	0.14	0.48
Thermal conductivity (W/m-k)	0.200	0.187	0.292
Colour (may vary)	Grey	Amber	Black
Thicknesses available (mm)†	5, 10, 15, 20 & 25	5, 10, 15, 20 & 25	5, 10, 15, 20 & 25
Maximum sheet size (mm)	1000 × 1200	2400 × 1200	2500 × 1250
Temperature resistance (°C)	+550 short term (Max) +300 long term (Max) −120 (Min)	+250 short term (Max) +210 long term (Max) −180 (Min)	+170 short term (Max) +110 long term (Max) −40 (Min)
Thicknesses tolerances (mm)§	±0.5 (TBF 5) ±0.7 (TBF 10) ±1.05 (TBF 15) ±1.4 (TBF 20) ±1.75 (TBF 25)	0/+0.2 (TBK 5, 10 & 15) 0/+0/3 (TBK 20 & 25)	0/+0.25 (TBL 5) +0.2/+1.5 (TBL 10) +0.3/+2.5 (TBL 15, 20 & 25)

* A2-s1, d0 fire-rated material
† Multiple plates can be provided for applications where thicknesses greater than 25mm are required. All materials can be supplied in non-standard thicknesses
§ Farrat TBL can be supplied to tighter tolerances

Equation (D.1). The characteristic values for design to BS EN 1993-1-8 should be converted to design values by using the partial safety factor γ_{M2}, which is defined as 1.25 in the UK National Annex.

Design – thermal performance

Finite element analysis is still currently the only way to numerically establish the performance of an elemental point connection. However, this is a time-consuming and complicated process which is infrequently used to assess details. There are few standard construction details between projects, so detailing of the building envelope and penetrations can vary significantly. As a result, the calculation of thermal performance and compliance can be complex.

There are two aspects to the thermal performance of the building envelope: heat loss and condensation risk. Both issues are covered by Building Regulations and guidance on meeting them is provided in various Approved Documents (England and Wales), Technical Handbooks (Scotland) or Technical Booklets (Northern Ireland).

These documents currently require heat loss and condensation risk to be assessed in accordance with the same British Standards, European Standards and Building Research Establishment (BRE) publications.

Finite element analysis thermal modelling not only considers the direct connection of materials, but also the significant elements surrounding the connection. These surrounding elements have such an impact on the result that they cannot be ignored in a simple calculation.

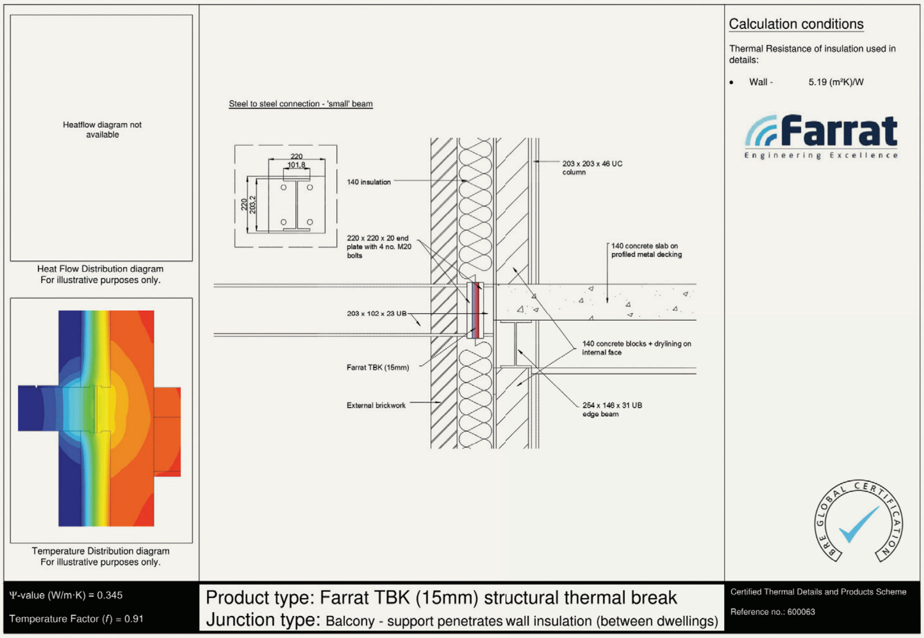
BRE analysis

In the absence of a full thermal model of the actual detail being used, typical details can be modelled and used as indicators of likely performance and used to specify materials that will meet design requirements using indicative details available online from the BRE, which can be relied upon in the absence of a full 3D model analysis.

The scheme database includes both BRE Certified Thermal Details and Products and Government Accredited Details. The third-party BRE global certification **(Figure 4)** can distinguish products and services from their competitors and give customers confidence about the thermal performance of the products. The database has been developed to enable details to be linked directly into SAP 2016 and is also featured within the BRE Home Quality Mark standard.

Several typical connection details have been analysed under the scheme to assist designers when specific modelling of their details is not undertaken.

After determining the thermal performance of the construction detail, either through modelling or using exemplar details for the smallest cross-sectional area of penetration/connection, the thickest thermal break plate able to be accommodated with the lowest thermal conductivity must be selected to ensure optimum performance.



↗**FIGURE 4:** Independently assessed and certified by BRE Global - Detail number: 600063. Product description: Farrat TBK (15mm) – Balcony: Steel-to-steel connection (small beam scenario) at 1500mm spacing

↗**FIGURE 5:** One and Two New Bailey, London – Farrat thermal breaks used to achieve BREEAM Excellent rating

Recommendations

Carry out a full analysis of the cold bridge–heat loss/condensation risk in conjunction with codified methodology to determine the thermal break requirements.

The best thermal performance will be obtained by:

- developing the smallest cross-sectional area of penetration/end connections
- using the smallest cross-sectional area of bolts through the connection
- using the thickest thermal break plate
- using materials with a low thermal conductivity value
- locating the thermal break connection within the insulated layer of the building facade/roof construction.

Structural design summary (steel connections)

Connections that include thermal break plates should be designed in accordance with the relevant design standards (e.g. BS EN 1993-1-8) or industry guidance (e.g. SCI publications).

The following additional checks should also be undertaken to ensure that:

- the thermal break plate can resist the applied compression forces
- any additional rotation due to the compression of the thermal break plate (including allowance for long term creep) is acceptable
- the shear resistance of the bolts is acceptable given that there may be a reduction in resistance due to:
  - packs – cl. 6.3.2.2 of BS 5950-1 or cl. 3.6.1(12) of BS EN 1993-1-8

- large grip lengths – cl. 6.3.2.3 of BS 5950-1 or BS EN 1993-1-8

For connections involving concrete and masonry, the material principles detailed above should be considered in conjunction with the relevant Eurocodes. All connections involving proprietary fixing systems (non-standard) may require consultation with the product supplier **(Figure 5)**.

Design

As with all construction components, correct handling and installation are a critical part of the performance. Attention should be paid to any specific manufacturer's requirements for handling; this should also include connection-specific labelling, material conformity certification and batch traceability to ensure avoidance of site and design validation issues.

As well as the simple evaluation of a compressive strength figure, account should also be taken of the material's ability to disperse loads from highly loaded points of a connection. This factor and a selected material's ability to deal with these loads should be addressed by the material manufacturer.

All material-to-material connections have the potential to rotate under load. Note that care should always be taken to a) ensure that the chosen structural thermal break can resist these loads, and b) to avoid compromising the short- and long-term performance of a connection with undue flexibility or excessive creep.

Structural thermal breaks **(Figure 6)** typically limit the extent of their load transmittance for design purposes to the transferal of compression loads. The main connection elements typically deal with shear loads. Notice should be taken of the effective connection lengths in relation to the thickness of structural thermal break specified. A thickness of 25mm would typically be the optimum without having to consider increasing the size of the bolt.

↗FIGURE 6: S2 Building, London – integrated Farrat structural thermal breaks

Fire performance

In most applications there are no requirements to meet any fire regulations. However, buildings over 18m or six storeys now have stricter requirements for building envelopes following the Grenfell Tower fire. Structural thermal breaks are excluded from the new Document B requirements despite being a key component in high-rise building facades; however, they can be produced with different grades of flammability and performance under fire loading. To maximise building safety, designers should look to choose a certified fire-resistant material wherever possible.

There are now fire-resistant structural breaks such as Farrat TBF (A2-s1, d0 fire performance classification to EN 13501-1) available where fire is a leading concern due to building height or the type of occupancy, such as a hospital or school.

Questions

To claim your CPD certificate, complete the module online by 31 August 2021 at: **www.istructe.org/industry-cpd**

1) In addition to reducing energy loss, what do structural thermal breaks mitigate the risk of?
☐ Fire
☐ Condensation
☐ Subsidence
☐ Erosion

2) Which is the simplest empirical calculation that can be carried out using the respective conductivity values and figures for the climatic environments into which they are due to be installed?
☐ X-value
☐ P-value
☐ U-value
☐ Z-value

3) What are the two main issues deriving from condensation?
☐ Mould and corrosion
☐ Corrosion and collapse
☐ Mould and flooding
☐ Flooding and collapse

4) What is still the only way to establish the performance of an elemental point connection?
☐ Steel element analysis
☐ Finite element analysis
☐ Psi element analysis
☐ Construction element analysis

5) In the absence of a full thermal model of the actual detail being used, where can you find typical details that can be modelled to use as indicators of likely performance?
☐ BRE
☐ BBA
☐ ABC
☐ CBBC

6) After determining the thermal performance of the construction detail, what thermal break plate must be selected to ensure optimum performance?
☐ The thinnest able to be accommodated with the lowest thermal conductivity
☐ The widest able to be accommodated with the lowest thermal conductivity
☐ The thickest able to be accommodated with the lowest thermal conductivity
☐ The most fire resistant able to be accommodated with the lowest thermal conductivity