Steel Construction and Thermal Bridging

Thermal bridging has become more of an issue following the introduction of the latest revision of Part L of the Building Regulations for England and Wales in April this year. Christopher Kendrick, Consultant to the SCI, examines the issues.

Thermal bridging refers to the additional heat loss from a building as a result of either geometry (for example at corners) or components of relatively high thermal conductivity (such as fixings and other structural elements) penetrating the insulated envelope. This additional heat flow must be added to the plane heat loss accounted for in the U-value to give a true measure of actual fabric heat loss.

1. HEAT LOSS

Both SAP 2005 and SBEM, the energy models, for domestic and non-domestic construction respectively, used to demonstrate Part L energy performance compliance, require thermal bridging heat losses to be included in the calculation. Repeating thermal bridges, such as frame elements, are included in the U-value, but non-repeating thermal bridges such as floor junctions, window and door junctions, eaves, verge and ridges form additional heat transfer paths. These can be accounted for by linear thermal transmission factors, ψ (known as psi values), measured in W/m.K for each thermal bridge. Total fabric conduction heat loss per Kelvin temperature difference is then given by:

$$\psi.L + \Sigma U.A$$

Where ψ is the linear thermal transmission coefficient (W/m.K)
L is the length of that thermal bridge (m)
U is the U-value of an element (W/m^2K)
A is the area of that element (m^2)

1.1 Domestic buildings

Accredited Construction Details (ACD's) for domestic construction, are available as .pdf documents from the internet(1) for many different types of feature which, if followed, enable designers to minimize thermal bridging. If Ψs not calculated explicitly for each thermal bridge, approximation factors may be used. For example in Appendix K of SAP 2005(2), thermal bridging heat loss HTB is assumed to be:

$$HTB = y.\ \Sigma A_{exp}$$

Where ΣA_{exp} is the overall exposed area of the building envelope y is a factor, either:
y = 0.08 (Accredited Construction Details used)
y = 0.15 (other details used)

Thermal bridging can thus add significantly to the overall fabric heat loss.

1.2 Non- domestic buildings

For building systems such as composite and built-up steel cladding, manufacturers can usually provide ψ values. Standard values are included in SBEM for metal cladding systems based on MCRMA details. However, for larger projects, it can be economic to calculate the thermal bridge losses separately for each detail. This is done by using two- and three-dimensional conduction analysis software, often working from the CAD drawings of details.

2. CONDENSATION

Although heat loss is a very important effect of thermal bridging, the more serious aspect as far as building occupiers are concerned arises from the low internal surface temperatures around the thermal bridge, which can lead to surface condensation. For non-absorbent surfaces such as steel, condensation can cause unsightly collection of moisture and dripping/pooling on surfaces beneath. For surrounding absorbent materials such as insulation products or plasterboard, interstitial condensation can occur, leading to loss of thermal performance, loss of structural integrity and mould growth. The local relative humidity need only be sustained at above 80% for mould growth to accelerate. Mould, as well as being unsightly, gives off spores that can cause bronchial problems and aggravates existing asthmatic conditions.

An indicator of condensation risk is provided by the temperature factor f_{Rsi}, a factor given by:

$$f_{Rsi} = \frac{t_{si} - t_{ao}}{t_{ai} - t_{ao}}$$

where t_{si} is internal surface temperature
t_{ao} is external air temperature
t_{ai} is internal air temperature

Minimum recommended values of f_{Rsi} depend upon the use of the building and its consequent internal relative humidity. For a dwelling, where cooking and washing can cause high humidity, a mandatory minimum of $f_{Rsi} = 0.75$ is stipulated. For swimming pools, a value of 0.9 is recommended, whereas for commercial buildings a value of 0.5 is allowable.

For more information, refer to the BRE Information Paper BRE 1/06 (3).

Figure 1: Typical apartment block used for thermal modeling

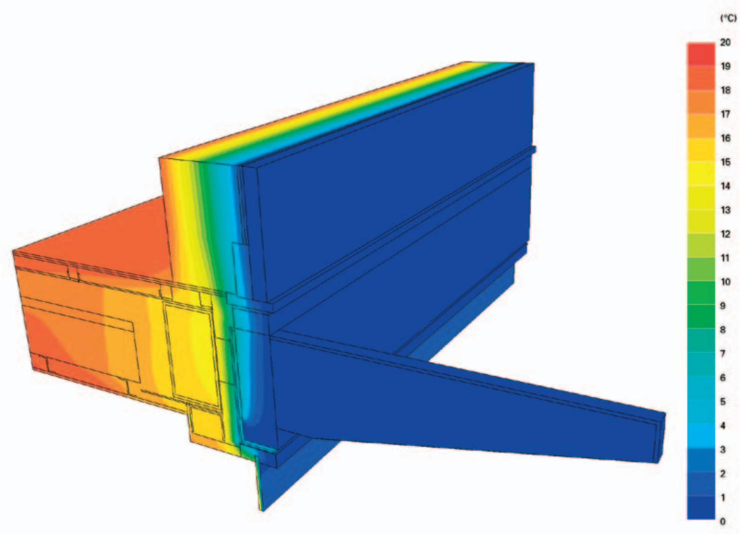

Figure 2: Cantilever balcony thermal modeled

3. MINIMISING THERMAL BRIDGING IN STEEL CONSTRUCTION

Steel has a relatively high thermal conductivity and therefore details need careful consideration. However, there are effective methods for incorporating steel components without causing unduly high heat loss or condensation risk.

Addition of local insulation, for example around beam elements that penetrate a wall, such as to support a roof overhang or canopy. Beams can be boxed in on the outside portion to a specified length and insulated with mineral wool. Provision of thermal breaks. Examples include composite cladding where the steel skin is separated at junctions by a layer of insulation and use of thermal pads beneath brackets in built-up cladding systems.

Slotted steel can significantly reduce thermal transfer. Overlapping lines of slots can reduce the equivalent thermal conductivity of light gauge steel studs by a factor of ten or more, and are also used with steel box-section lintels.

Lower conductivity fixings such as stainless steel bolts or screws with a thermal conductivity less than a third that of steel can be used and can have a positive effect.

Proprietary products currently on the market in the UK, constructed from insulation and stainless steel, which connect (for example) steel beams that penetrate the insulated envelope of a building.

Studies by SCI in conjunction with Oxford Brookes University have demonstrated that current practices can meet the Part L requirements. A multi-storey residential building example with Slimdek floors and steel cantilevered balconies was chosen to illustrate the effects of the three SAP options for calculating thermal bridge heat loss. See Figure 1.

	Top floor corner (1)	*Mid-floor corner (2)*	*Mid-façade (3)*
Target Emissions Rate*	23.530	20.650	19.650
Option 1: (H_{tb} = 0.08A)			
Dwelling Emissions Rate	21.420	18.550	17.640
SAP Rating	82.000	85.000	85.000
Option 2: (H_{tb} = 0.15A)			
Dwelling Emissions Rate	22.760	18.990	18.100
SAP Rating	83.000	85.000	85.000
Option 3: (calculated H_{tb})			
Dwelling Emissions Rate	21.810	19.030	18.340
SAP Rating	83.000	85.000	85.000

Table 1. Carbon dioxide Emission Rate (kg $CO_2/m^2/yr$)*

Linear thermal transmission (ψ) was calculated for all thermal bridges using BISCO and TRISCO software. See Figure 2. These values were then multiplied by the length of each thermal bridge to give a total value for thermal bridging (H_{tb}) for three types of apartment. Results in Table 1 show that the design can pass SAP by using the allowed approximation for non-accredited construction details, and there is no need to calculate linear thermal bridging separately in this case.

4. CONCLUSIONS

Thermal bridging can be minimized in steel construction by good design practices, perhaps utilizing thermal modeling techniques as demonstrated in this article, specifying the correct materials in the correct locations, and with application of products currently on the market in the UK. Regardless of regulations, all building designers have a responsibility to produce buildings that are both energy efficient and not prone to problems caused by condensation on internal surfaces.

REFERENCES

http://www.planningportal.gov.uk/england/professionals/en/1115314255954.html

The Government's Standard Assessment Procedure for Energy Rating of Dwellings, BRE 2005

Ward T, Assessing the effects of thermal bridging at junctions and around openings, BRE IP1/06, Building Research Establishment 2006

LATERAL TORSIONAL BUCKLING AND SLENDERNESS – ERRATUM

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In the October 2006 edition of the NSC the technical article on Lateral torsional buckling and slenderness contained the following errors.

Section 3 pages 32 and 34 –
all the λ_{LT} in the text for Eurocode 3 should be $\bar{\lambda}_{LT}$.

Section 3.2 page 34 – the equation for $\bar{\lambda}_{LT}$ should be replaced by the following equation:

$$\bar{\lambda}_{LT} = \frac{1}{\sqrt{C_1}} 0.9 \bar{\lambda}_z \sqrt{\beta_w}$$

The following equation should be added above the definition for W_y

$$\beta_w = \frac{W_y}{W_{pl,y}}$$