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Thermal Performance of Steel Beam Junctions using Different Connection Methods

Client

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Authors

C C Kendrick and S Resalati

OISD Technology

Department of Architecture, School of the Built Environment, Oxford Brookes University, Gipsy Lane Campus Oxford OX3 0BP
Phone: +44 (0) 1865 483208, Fax +44 (0) 1865 483298, Email oisdtech@brookes.ac.uk
<http://www.brookes.ac.uk/schools/be/oisd/act/technology/index.html>

1. Objective

The aim of this investigation was to determine the heat loss, minimum surface temperature and temperature factor (f_{RSi}), and equivalent conductivity resulting from use of Schock Isokorb KST units connecting a steel I-beam, and to compare these values with alternative connection methods and with a continuous beam. Calculation was by means of three-dimensional finite difference analysis.

Since this modelling was undertaken, the insulation has been upgraded to Neopor with a lower thermal conductivity of 0.031W/mK rather than 0.035W/mK. This change will slightly enhance the performance of the units in comparison with the modelled results presented in this report.

2. Description

A steel I-beam is assumed to pass through an 80mm layer of insulation. This could represent a roof beam running through the building envelope to support an exterior canopy or overhang. Three types of situation were studied:

- HEA200 I-beam separated by thermal isolator unit Isokorb KST 16 and HEA240 I-beam separated by thermal break unit Isokorb KST 22
- Single HEA200 I-beam passing straight through the insulation layer
Single HEA240 I-beam passing straight through the insulation layer
- HEA240 I-beam divided by a PTFE 'thermal pad'

Schock Isokorb KST units (Figure 1) consist of the top ZST unit, designed to take tensile forces, and the lower QST unit, designed to take compressive forces. The units are separated by a layer of polystyrene foam, the depth of which depends upon the application. 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 as required. The QST unit includes a stainless steel box section to cope with compressive forces. Figures 2 and 3 show the two sizes investigated, KST 16 and KST 22, using M16 and M22 threads respectively.

Welded end plates 220mm wide x 250mm deep x 20mm thick were assumed to be used with KST 16 units, and plates 260mm x 322mm x 40mm thick were used with the KST 22 unit and the 'thermal pad' configuration.

The three-dimensional models were constructed using an orthogonal approximation, for example Figure 4.

The beams used were dimensioned as follows:

HEA200

Overall Width: 200mm
Overall Depth: 190mm
Flange width: 10mm
Web width: 6.5mm

HEA240

Overall Width: 240mm
Overall Depth: 230mm
Flange width: 12mm
Web width: 7.5mm

Figure 5. illustrates the modelled HEA240 beam passing through the insulation layer ($\lambda = 0.035\text{W/mK}$)

To compare the performance of Schock Isokorb units with another method of thermal isolation that may be considered as an alternative, the HEA240 beam was modelled in two halves, each with a welded end plate, separated by a 'thermal pad' and connected by four M24 bolts. This model is shown in Figure 6. Results were determined for 5mm, 10mm and 20mm layers, with steel and stainless steel bolts.

3. Calculations

TRISCO software from Physibel was used to construct three dimensional models of the applications described above in accordance with BS EN ISO 10211:1 (1996) ⁽¹⁾. Steady state solution was by means of the iterative finite difference method.

Equivalent conductivity was calculated by replacing the Isokorb units with an 80mm thick slab of notional material, the conductivity of which was adjusted until the heat flows matched. The reference areas used in each case are indicated the below the results Table 1.

Table 1. Thermal conductivities ⁽²⁾

Material	Thermal conductivity (W/mK)
Steel	50
Wall insulation	0.035
Stainless steel	17
Stainless steel (Isokorb)	15
Polystyrene foam (Isokorb)	0.035
PTFE	0.25

Boundary conditions

In the UK, surface resistances (R_s) are set in accordance with BS6946 ⁽³⁾ to determine U-values, thermal bridging heat loss, minimum surface temperature (and hence temperature factor). For walls:

$$\begin{array}{ll} \text{Inside:} & t_{ai} = 20^\circ\text{C} \quad R_{si} = 0.13\text{m}^2\text{K/W} \\ \text{Outside:} & t_{ae} = -5^\circ\text{C} \quad R_{so} = 0.04\text{m}^2\text{K/W} \end{array}$$

In Germany, the surface resistances are set by DIN 4108-2 ⁽⁴⁾, which calls for different values to be used for determining minimum internal surface temperatures and hence temperature factor:

$$\begin{array}{ll} \text{Inside:} & R_{si} = 0.25\text{m}^2\text{K/W} \\ \text{Outside:} & R_{so} = 0.04\text{m}^2\text{K/W} \end{array}$$

Both results are presented in this report.

4. Results and conclusions

Table 2. presents the equivalent thermal conductivity of a block of homogenous material replacing the Isokorb unit between the welded steel end plates, the heat loss through the thermal bridge, the minimum internal surface temperature of the wall and the temperature factor. The latter two quantities were calculated for two different boundary conditions as stated above to enable comparison with the earlier German study.

In the UK, the temperature factor (f_{RSi}) is used to indicate condensation risk as described in BRE IP1/06 ⁽⁵⁾, a document cited in Building Regulations Approved Documents Part L1⁽⁶⁾ and L2 ⁽⁷⁾. For dwellings, f_{RSi} must be greater than or equal to 0.75, and for commercial buildings it must be greater than or equal to 0.5, calculated using an internal surface resistance of $0.13\text{m}^2\text{K/W}$.

It can be seen from the results that the Isokorb KST16 and KST22 units, with $f_{RSi} = 0.82$ and 0.81 respectively, exceed these values and will therefore meet the requirements of Building Regulations Approved Documents L1 and L2. The results for continuous beams and beams separated by 5, 10 and 20mm PTFE pads show that they all fail to meet the requirements laid down in the Building Regulations for dwellings. Furthermore, continuous beams and beams separated by 5mm and 10mm PTFE pads are also marginal or fail against the Building Regulations for commercial property.

Temperature distributions are shown in Figures 7 to 14.

5. References

- 1) BS EN ISO 10211-1:1996, Thermal Bridges in Building Construction – Heat flows and Surface Temperatures, General Calculation Methods BSI, 1996
- 2) Test Report P7-064e/2005, Calculation of Thermal Insulation Characteristics of Cantilevering Steel Constructions with Different Connections, Fraunhofer Institute, 2005
- 3) BS6946:1997, Building Components and Building Elements – Thermal Resistance and Thermal Transmittance – Calculation method, BSI 1997
- 4) DIN4108-2:2003-07: Wärmeschutz und Energie-Einsparung in Gebäuden – Teil 2: Mindestanforderungen an den Wärmeschutz. Beuth Verlag, Berlin
- 5) Ward T, Assessing the effects of thermal bridging at junctions and around openings, BRE IP1/06, Building Research Establishment 2006
- 6) Building Regulations Part L, Conservation of Fuel and Power, Approved Document L1, Conservation of Power in New Dwellings, April 2006
- 7) Building Regulations Part L, Conservation of Fuel and Power, Approved Document L2, Conservation of Power in New Buildings other than Dwellings, April 2006

Table 2. Calculation results

Description	Internal surface resistance	Equivalent thermal conductivity	Thermal bridge heat loss	Minimum surface temp	Temperature factor
	R_{si} m ² K/W	λ_{eq} W/mK	χ W/K	°C	f_{RSi} -
Isokorb KST 16	0.13	0.70 ⁽¹⁾	0.26	15.5	0.82
	0.25			13.8	0.75
Steel I-beam HEA200 passing through insulation	0.13	3.2 ⁽¹⁾	0.77	7.7	0.51
	0.25			5.7	0.43
Isokorb KST 22	0.13	0.87 ⁽²⁾	0.43	15.2	0.81
	0.25			13.7	0.75
Steel I-beam HEA240 passing through insulation	0.13	3.48 ⁽²⁾	1	7.5	0.5
	0.25			5.4	0.42
5mm PTFE, stainless steel bolts	0.13	5.8 ⁽²⁾	1.3	6.8	0.47
	0.25			4.5	0.38
5mm PTFE, steel bolts	0.13	7.6 ⁽²⁾	1.4	5.8	0.43
	0.25			3.5	0.34
10mm PTFE, stainless steel bolts	0.13	3.9 ⁽²⁾	1.1	8.6	0.55
	0.25			6.2	0.45
10mm PTFE, steel bolts	0.13	5.7 ⁽²⁾	1.3	6.9	0.48
	0.25			4.5	0.38
20mm PTFE, stainless steel bolts	0.13	0.55 ⁽²⁾	0.876	10.7	0.62
	0.25		0.711	7.7	0.50
20mm PTFE, steel bolts	0.13	1 ⁽²⁾	1.1	8.4	0.53
	0.25		0.855	5.3	0.412
Isokorb KST 16		0.92 ⁽³⁾			
Isokorb QST 16		0.62 ⁽⁴⁾			
Isokorb ZST 16		0.25 ⁽⁴⁾			
Isokorb KST 22		1.41 ⁽³⁾			
Isokorb QST 22		0.78 ⁽⁴⁾			
Isokorb ZST 22		0.42 ⁽⁴⁾			
Isokorb QST 16		1.5 ⁽⁵⁾			
Isokorb ZST 16		0.75 ⁽⁶⁾			
Isokorb QST 22		2.05 ⁽⁵⁾			
Isokorb ZST 22		1.34 ⁽⁶⁾			

(1) Reference area 250mm x 180mm (as per Isokorb KST 16 area used)

(2) Reference area 300mm x 180mm (as per Isokorb KST 22 area used)

(3) Reference area 190mm x 180mm (as per Isokorb KST area of insulating body)

(4) Reference area 190mm x 180mm (as per Isokorb unit with additional insulation)

(5) Reference area 80mm x 180mm (as per Isokorb QST16/22 area)

(6) Reference area 60mm x 180mm (as per Isokorb ZST 16/22 area)



Figure 1. Schöck Isokorb KST 16 unit

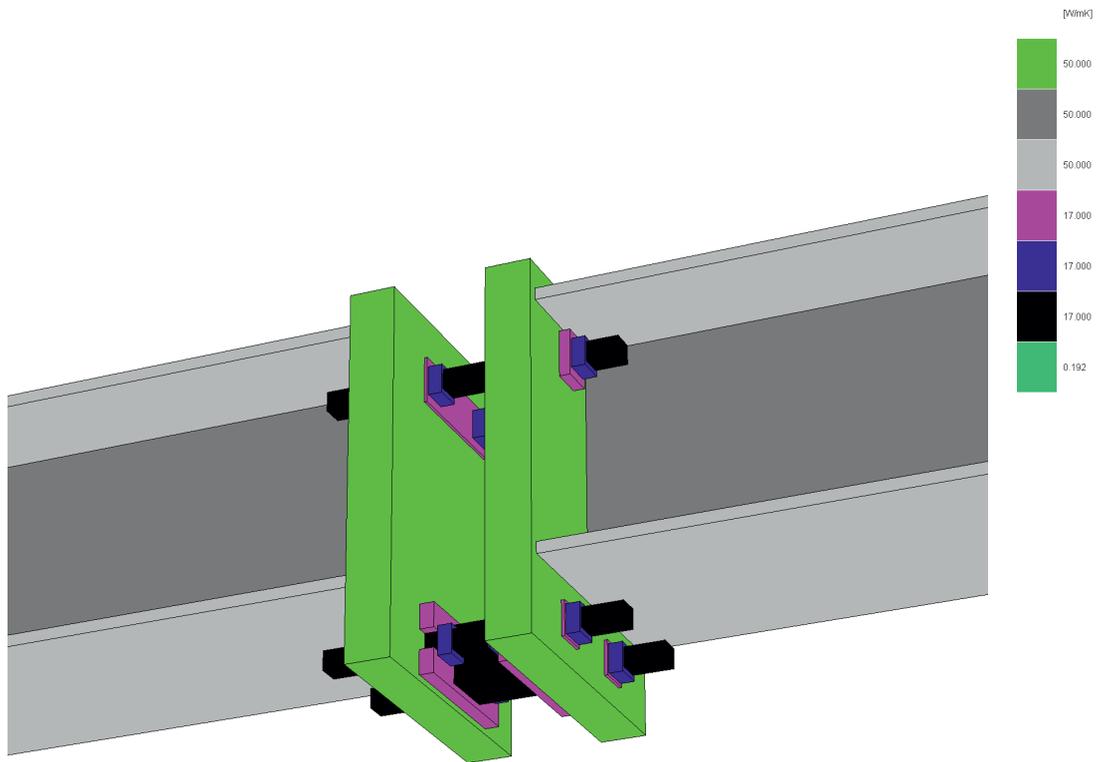


Figure 4. TRISCO model of KST 22 (insulation omitted for clarity)

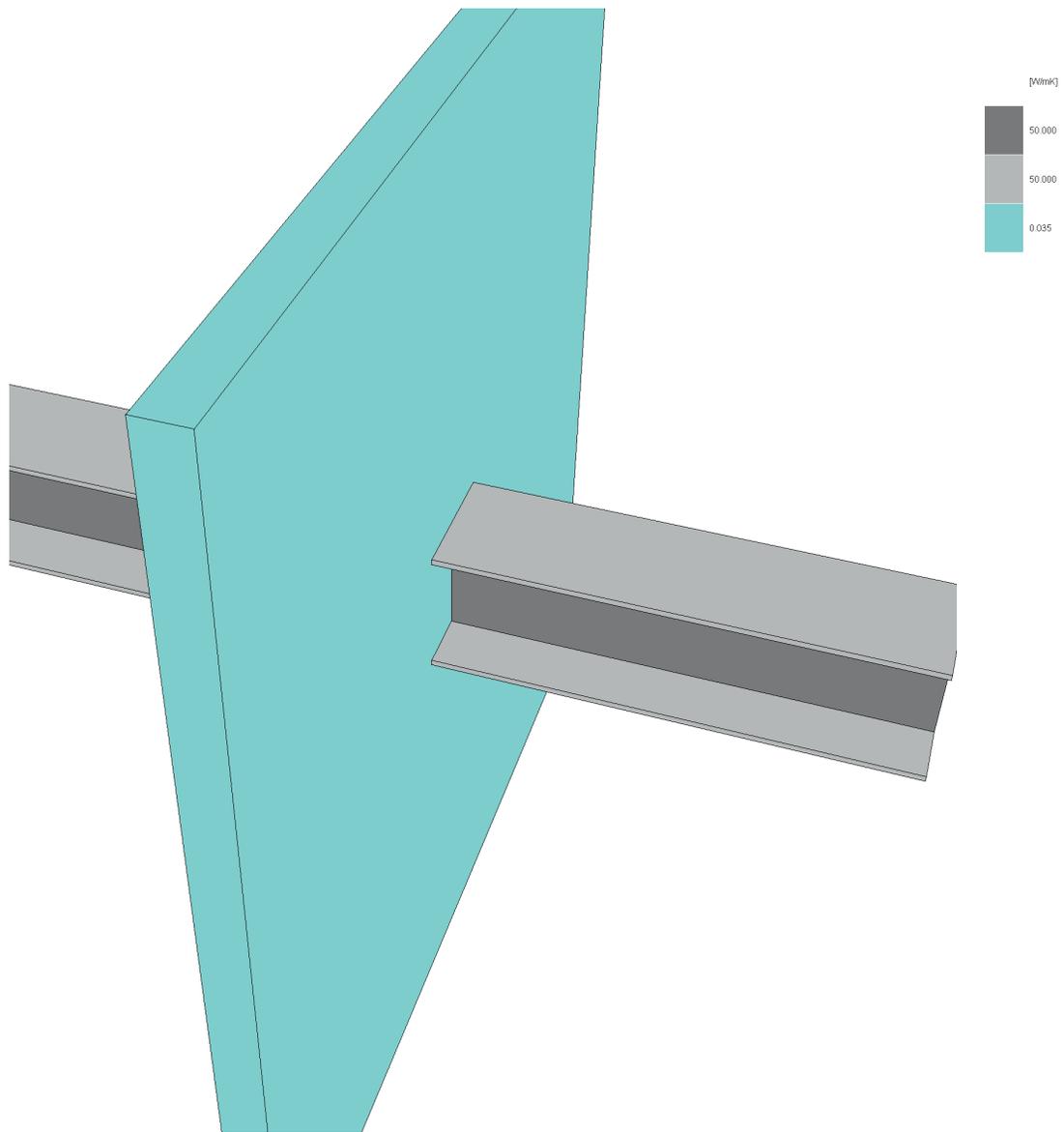


Figure 5. HEA240 beam passing through 80mm insulation

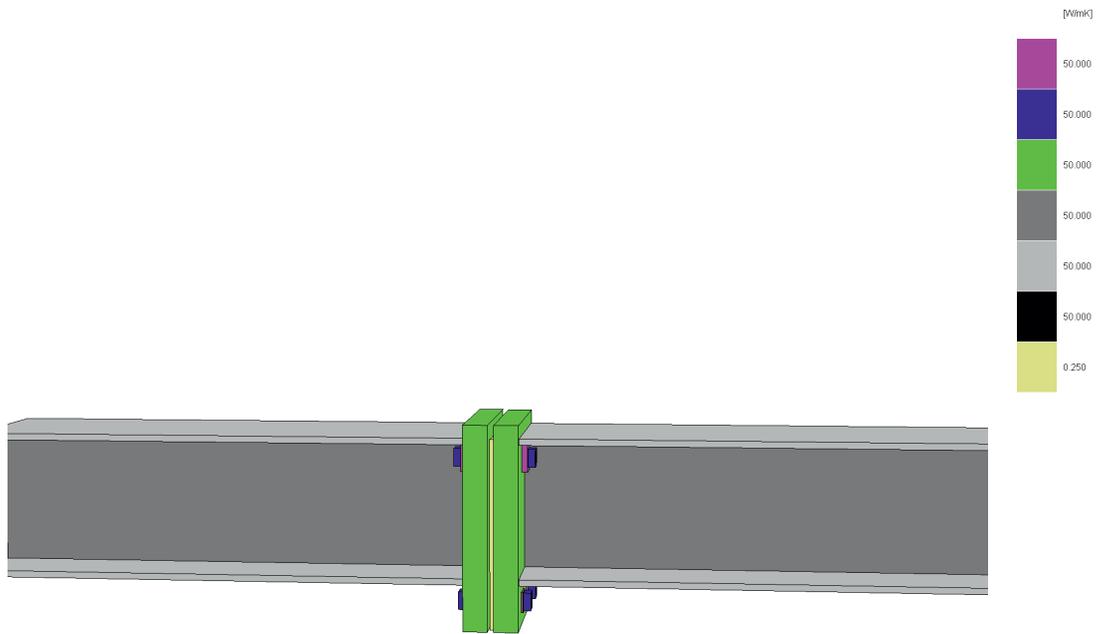


Figure 6. Bolted beam connection with 10mm PTFE (wall insulation omitted)

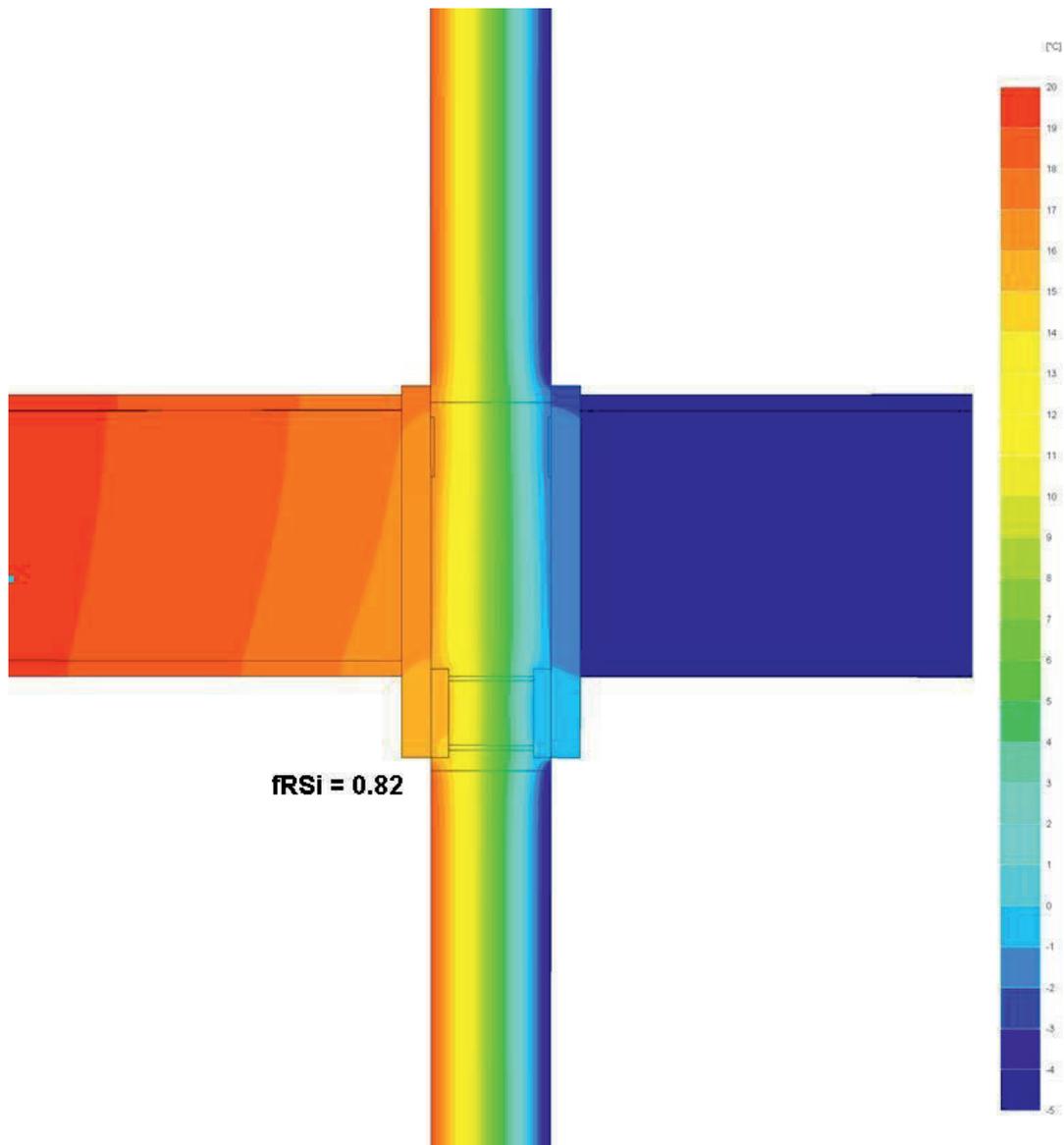


Figure 7. Temperature distribution, KST16 with HEA200 beam

This detail **conforms** with UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($f_{RSi} = 0.75$)

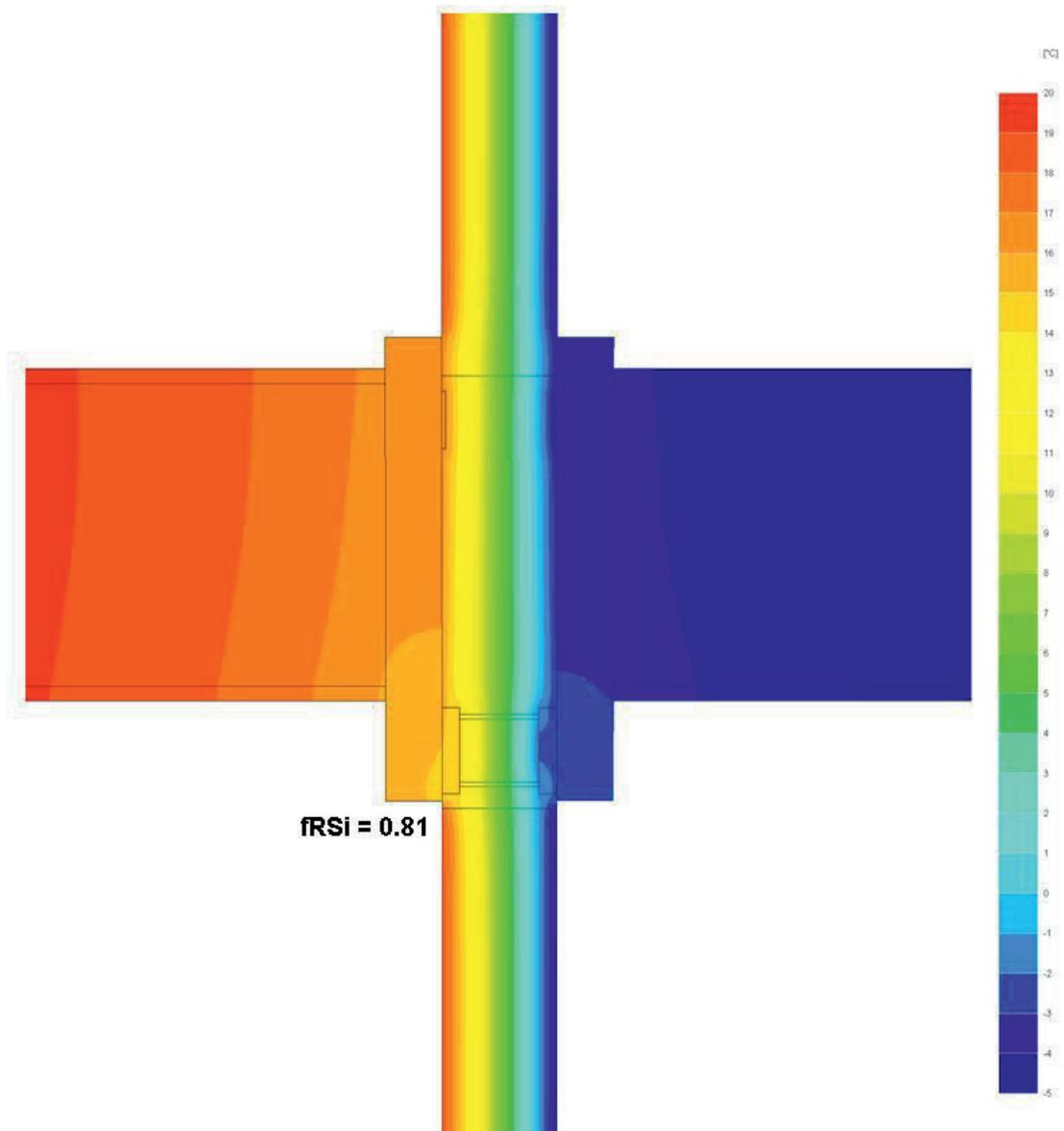


Figure 8. Temperature distribution, KST 22 with HEA240 beam

This detail **conforms** with UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($fR_{si} = 0.75$)

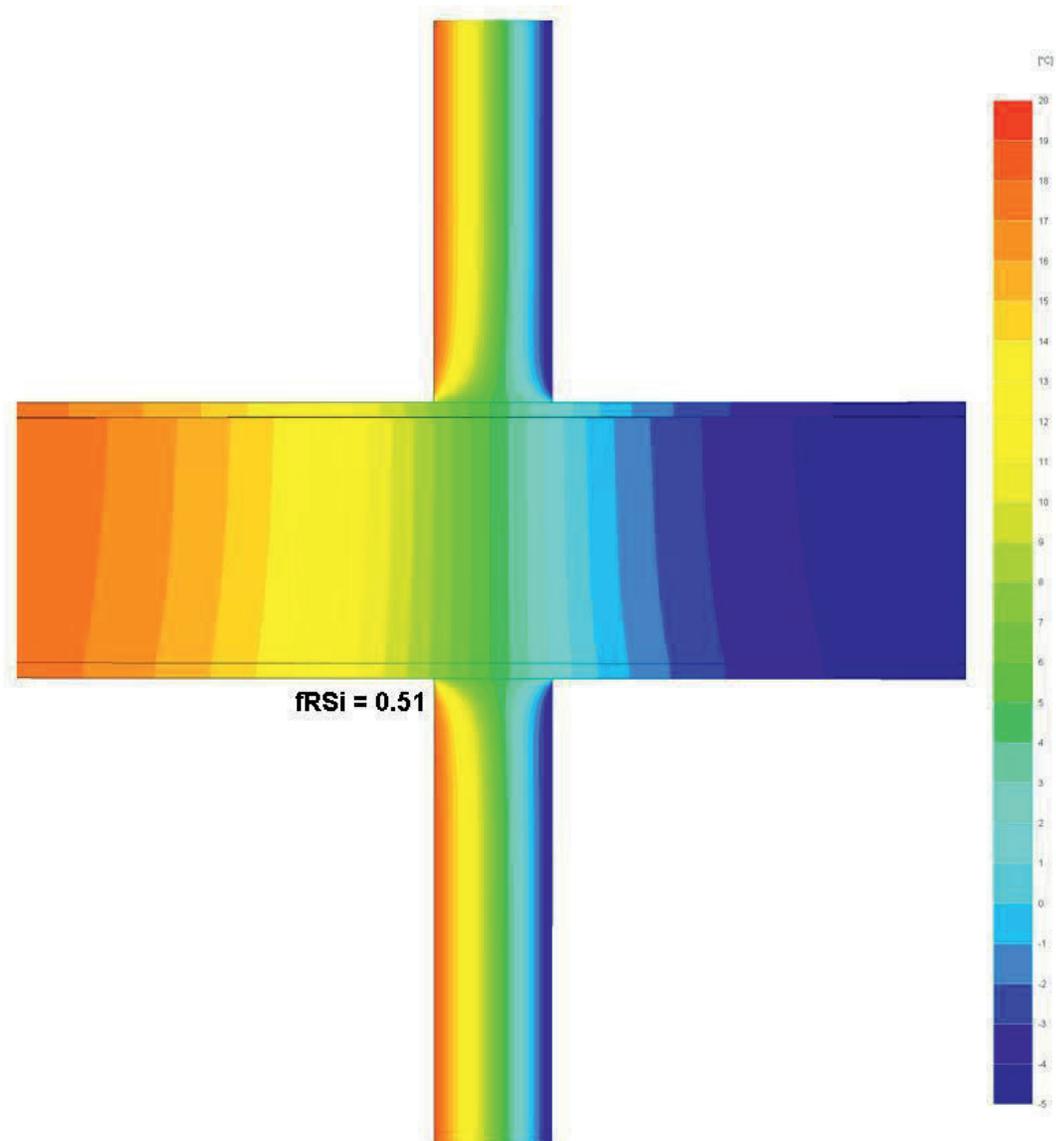


Figure 9. Temperature distribution, HEA200 beam through 80mm insulation

This detail does NOT conform to UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($fR_{si} = 0.75$)

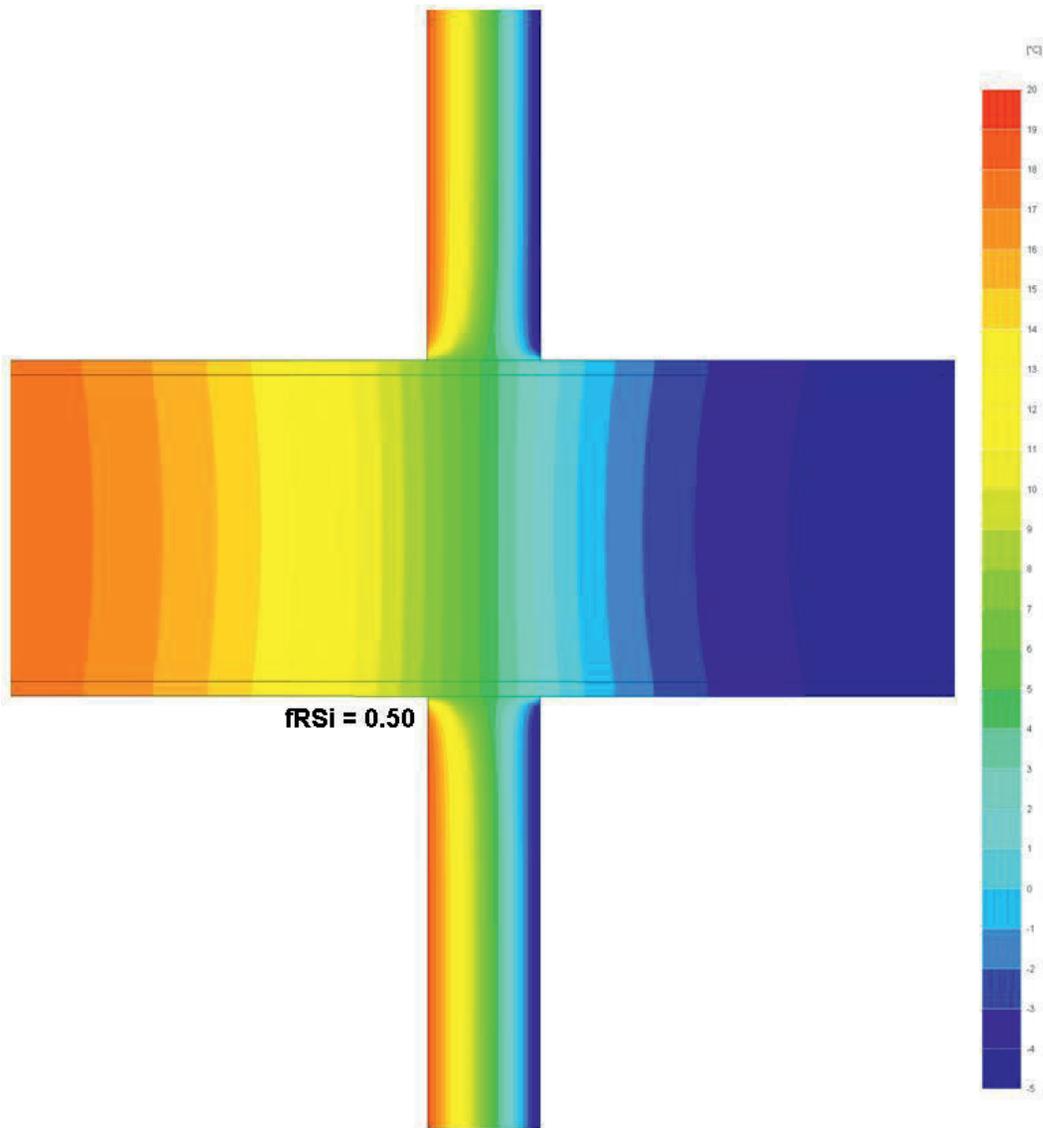


Figure 10. Temperature distribution, HEA240 beam through 80mm insulation

This detail does NOT conform to UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($fR_{si} = 0.75$)

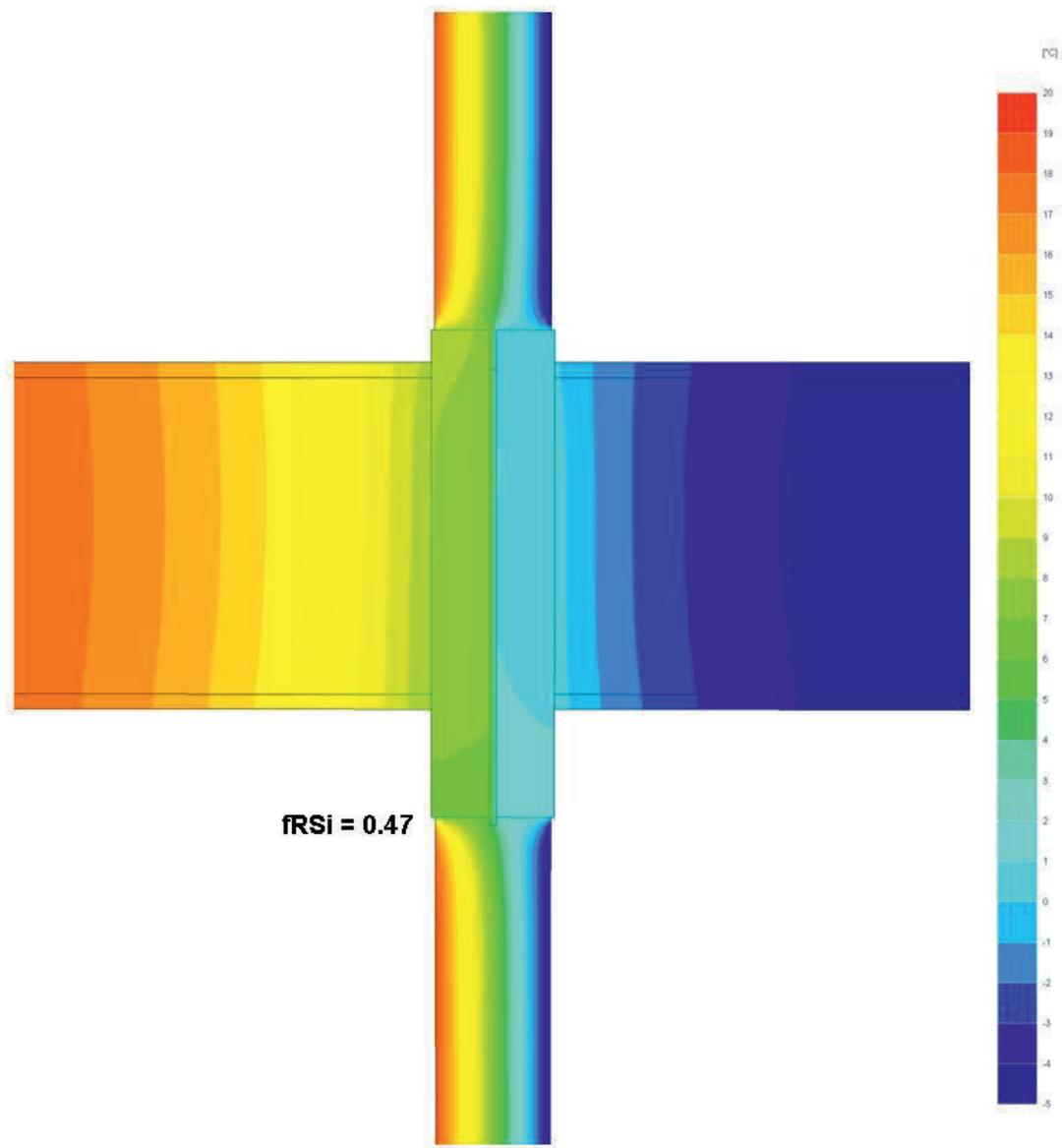


Figure 11. Temperature distribution, 5mm PTFE, stainless steel bolts

This detail does NOT conform to UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($f_{RSi} = 0.75$)

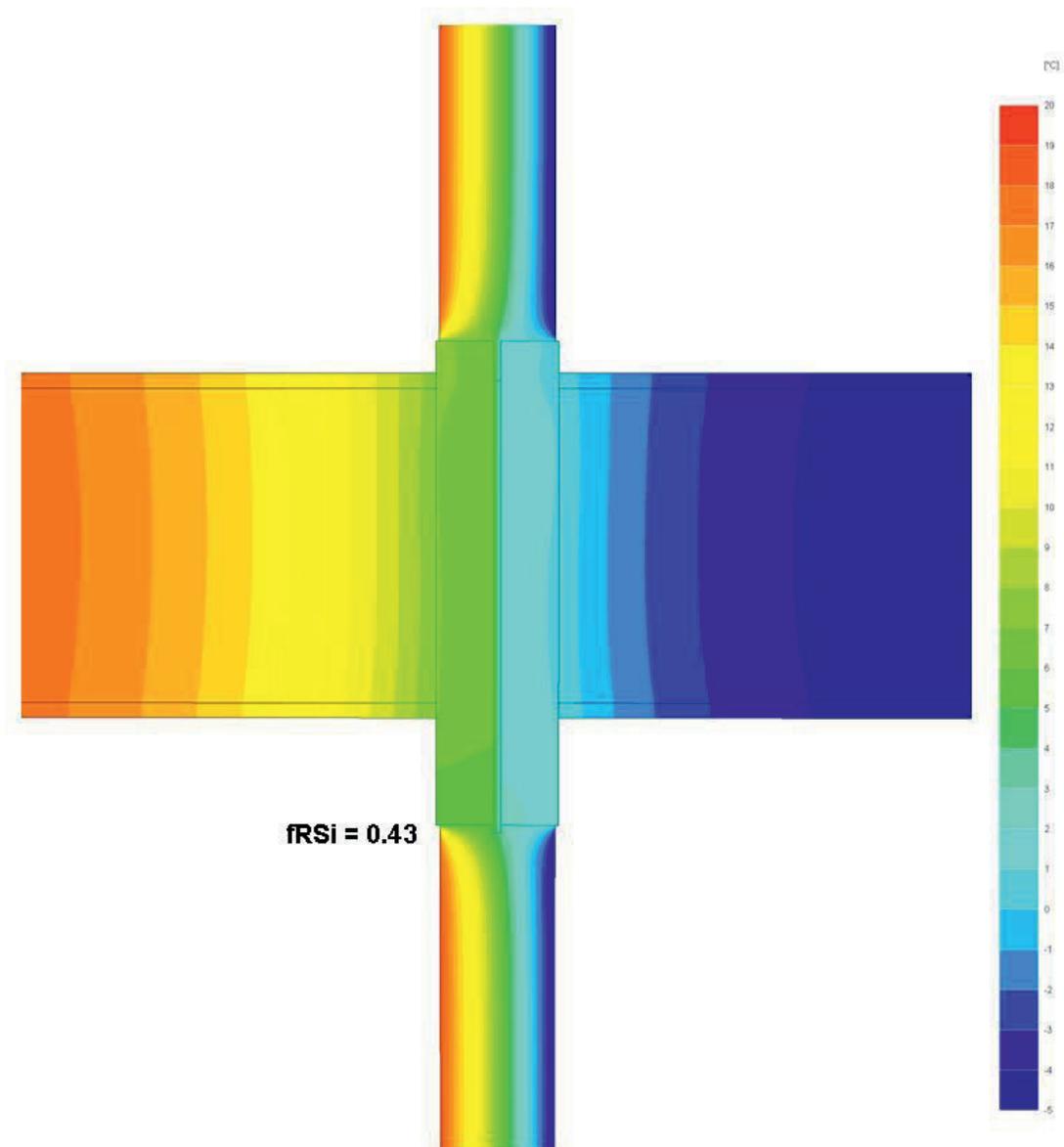


Figure 12. Temperature distribution, 5mm PTFE, steel bolts

This detail does NOT conform to UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($f_{RSi} = 0.75$)

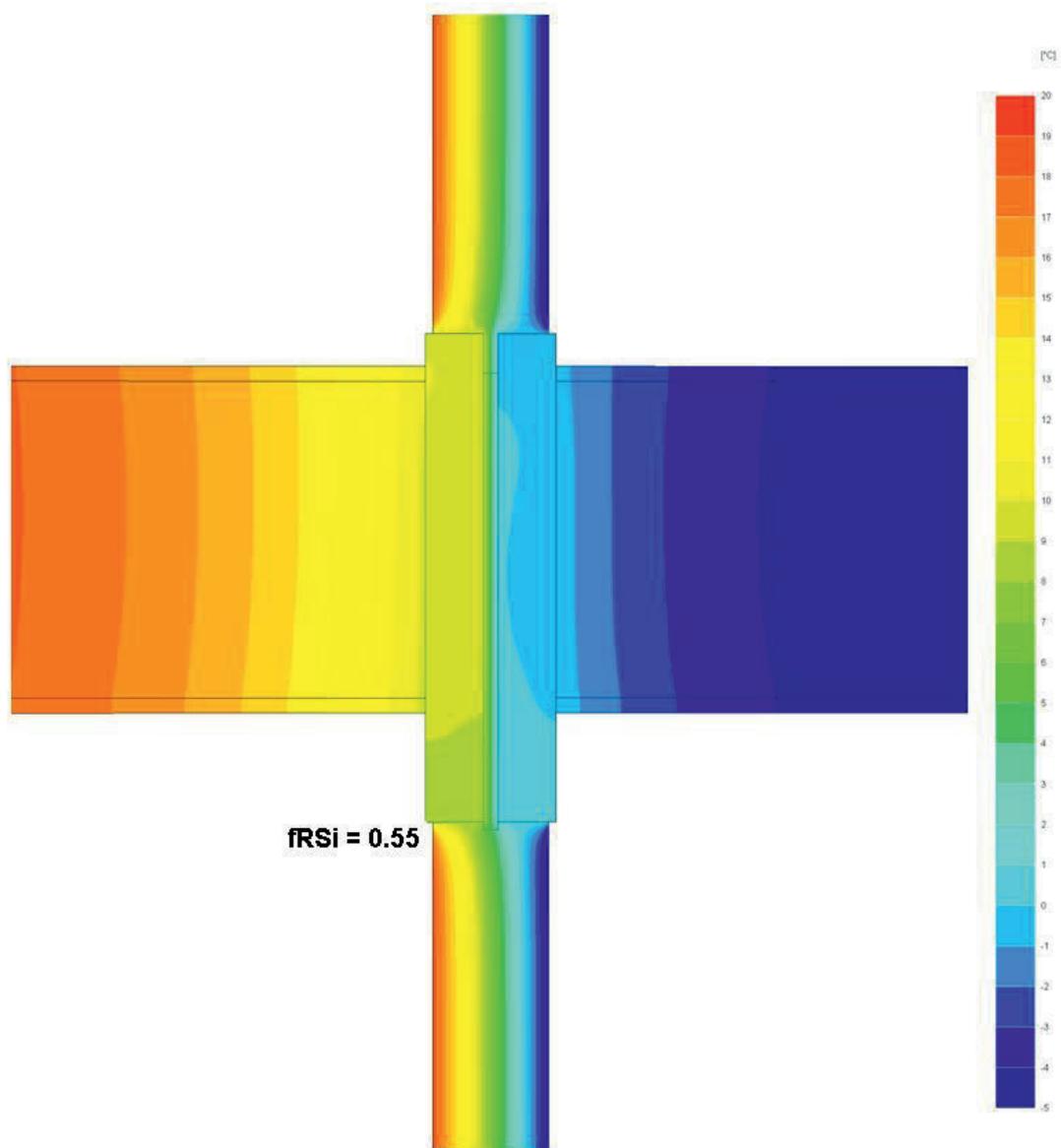


Figure 13. Temperature distribution, 10mm PTFE, stainless steel bolts

This detail does NOT conform to UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($fR_{si} = 0.75$)

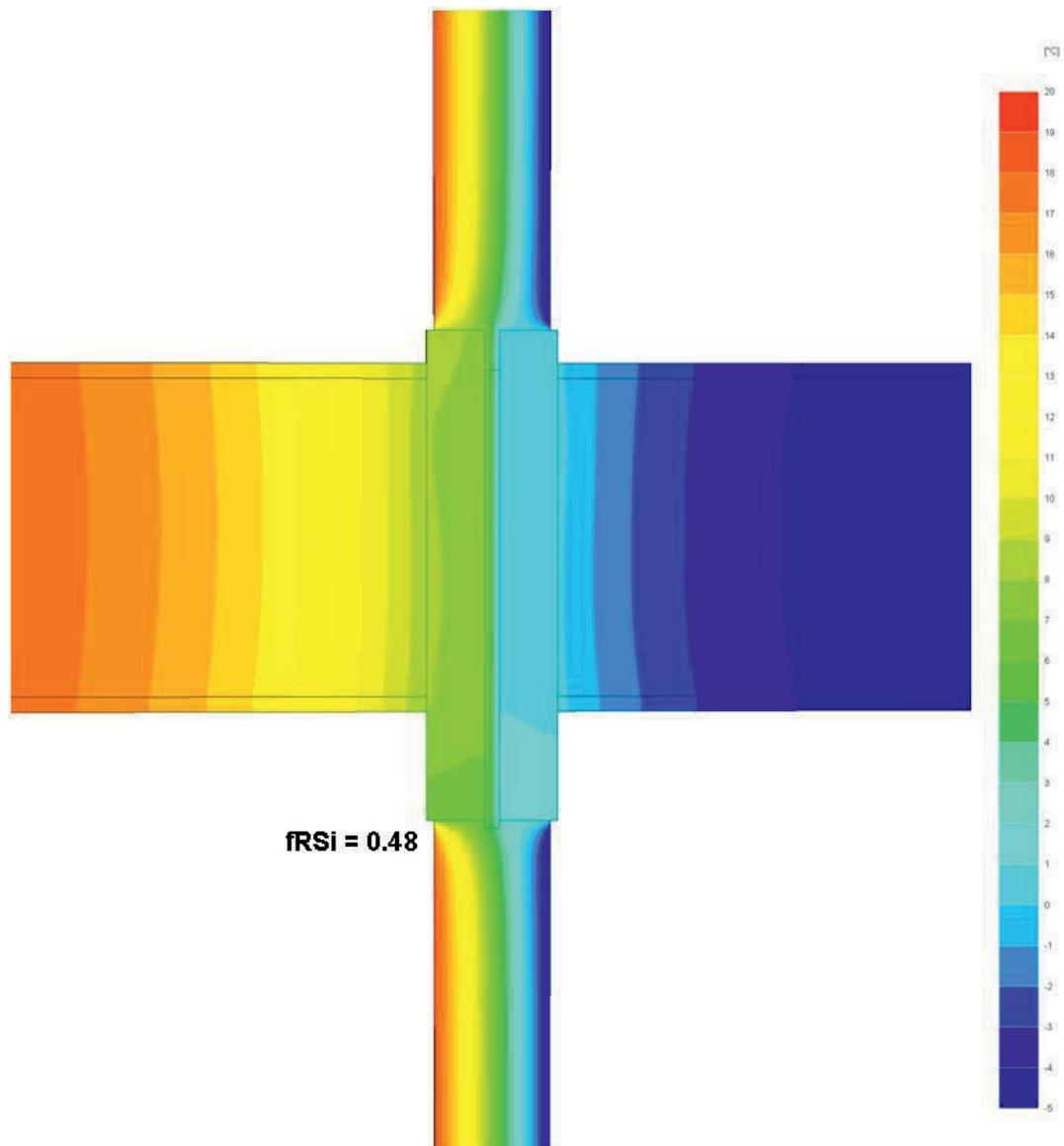


Figure 14. Temperature distribution, 10mm PTFE, steel bolts

This detail does NOT conform to UK Building Regulations Part L requirements for minimum temperature factor in dwellings ($fR_{si} = 0.75$)