Thermal bridging modelling of Ty Unnos junction details

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Prepared by

Name Caroline Weeks

Position Senior Consultant – BRE Wales

Signature

Reviewed by

Name Colin King

Position Associate Director – BRE Wales

Date 23rd March 2012

Signature

BRE Wales
Ethos
Kings Road
Swansea Waterfront
SA1 8AS
T + 44 (0) 1792 630100
F + 44 (0) 1792 630101
E walesenq@bre.co.uk
www.bre.co.uk

Executive Summary

BRE Wales were commissioned by WoodKnowledge Wales to carry out modelling on a range of Ty Unnos construction details in order to calculate the linear thermal transmittance, ψ, of the junctions. This information is utilised in SAP calculations for compliance with Building Regulations Approved Document Part L. Thermal bridging data is also used when assessing a building against the Passivhaus standard, though the conventions used for Passivhaus are different to those used for UK Part L calculations; namely, junctions are measured to internal dimensions in the UK but to external dimensions for Passivhaus, which fundamentally changes the thermal bridging/ ψ-values. For this study, ψ-values have been calculated to both standards. However, care should be taken to ensure the correct values are used for the relevant circumstances.

The relative complexity of the Ty Unnos construction system, particularly at key junctions where the Ty Unnos structural beams are present, make the derivation of the whole heat loss from the building more complex compared to other simpler systems. To truly represent the impact of the construction methodology, it has been necessary to model additional χ –values to represent occurrences of point thermal bridges. This report details how each of the following heat loss characteristics should be used in conjunction with each other for the Ty Unnos system.

Overall, heat loss from any building will be represented by:

- U values, applied over the area of the respective plane elements (W/m^2K)
- Ψ-values, applied over the length of the respective junctions (W/m·K)
- χ -values, applied to the number of occurrences of the particular point thermal bridges (W/K)

The ψ-values modelled for the demonstration Ty Unnos house to UK Regulations all fall below the default values that would otherwise be used for SAP assessments, which will benefit the modelled energy demand within SAP.

For Passivhaus, junctions with a ψ-value less than 0.01 W/m·K are considered ‘thermal bridge free’ and do not need to be taken into account within the modelling. However, any junctions above this limit will need to be represented. While many of the Ty Unnos junctions modelled for Passivhaus actually have negative ψ-values, the Ground floor/ External wall and Intermediate floor/ External wall junctions do exceed 0.01 W/m·K. Whether or not this is likely to be an issue for a Passivhaus model will depend on many other factors and how closely the overall building design sits within each of the Passivhaus limiting parameters.

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1 Introduction/ Background

Thermal modelling has been carried out on Ty Unnos construction details in order to calculate the linear thermal transmittance, ψ (pronounced 'saɪ'), associated with the junctions. This information is utilised in SAP calculations for compliance with Building Regulations Approved Document Part L. Where the thermal transmittance for the junctions is not confirmed by modelling, projects will be required to use default values within SAP that may detrimentally affect the overall energy performance calculated for the building.

Thermal bridging data is also used when assessing a building against the Passivhaus standard, though the conventions used for Passivhaus are different to those used for UK Part L calculations; namely, junctions are measured to internal dimensions in the UK but to external dimensions for Passivhaus, which fundamentally changes the thermal bridging/ ψ-values. For Passivhaus, junctions with a ψ-value less than 0.01 W/m·K are considered 'thermal bridge free' and do not need to be taken into account in the overall heat transfer through the building fabric. However, any junctions above this limit do need to be taken into account.

There are two effects that can contribute to the linear thermal transmittance of a junction detail and indeed both effects are often present together. One is a geometric effect that results from internal and external areas at the junction not being equal or the dimension system used, such as overall internal dimensions. The other effect is a constructional effect. For example, where the insulation level changes, e.g. a change in its thickness or thermal conductivity. Construction thermal bridges will also exist where materials with high thermal conductivity penetrate the insulation layer. Thermal bridges that apply over a defined length, such as the perimeter of an intermediate floor, are represented as ψ-values. However, in instances where the additional heat loss applies to a single point rather than acting over a length, it is represented as a χ-value (pronounced 'kaɪ').

Overall, the total heat loss from any building will be represented by:

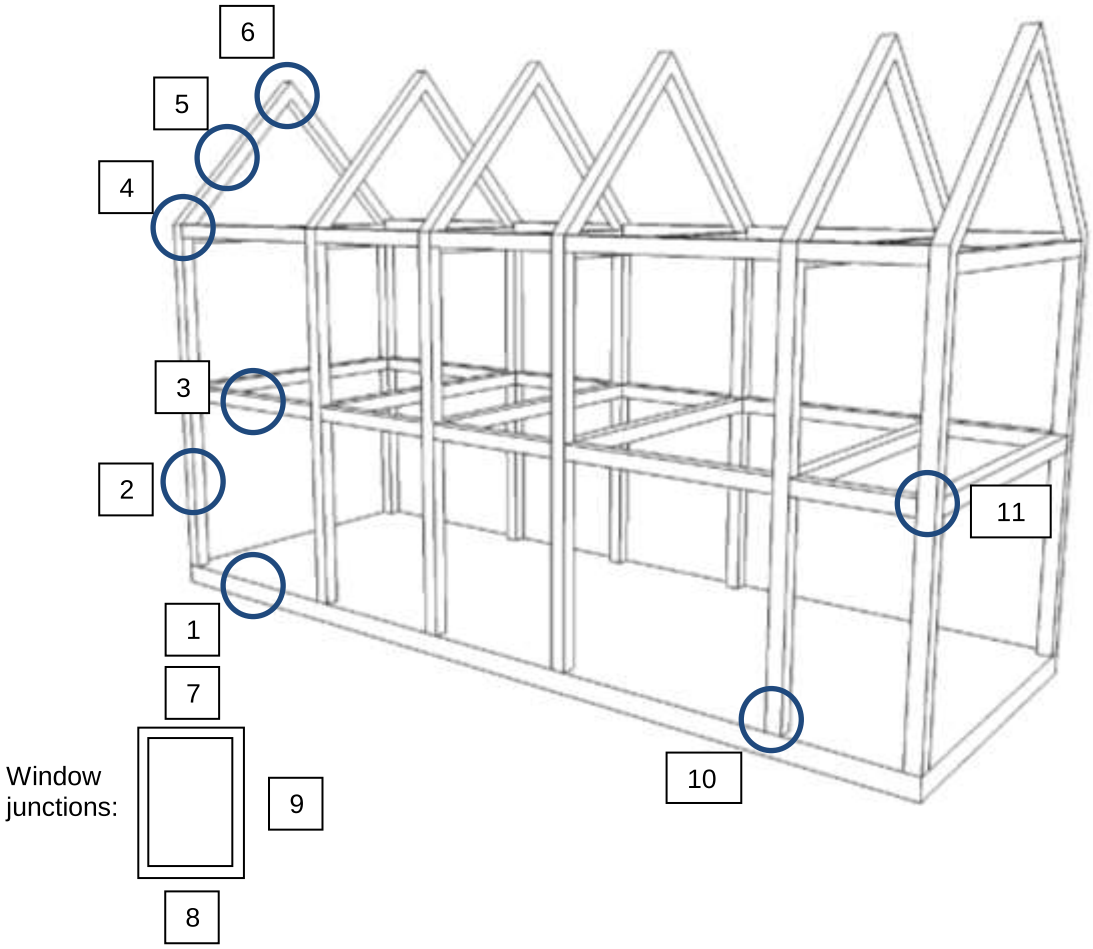
- U values, applied over the area of the plane elements (W/m^{2}K)
- Ψ-values, applied over the length of each respective junction (W/m·K)
- χ-values, applied to the number of occurrences of a particular point bridge (W/K)

For this project, the following junctions were prioritised, as indicated in Table 1 and Figure 1. The relatively unusual nature of the construction meant that some junctions required complex 3D modelling in order to account for the behaviour of the 'connecting pins' where the Ty Unnos beams meet, which are represented as χ-values. The treatment of these additional junctions for SAP and Passivhaus purposes is discussed in Section 4.

Table 1: Range of junction details modelled for the Ty Unnos demonstration house

Number in diagram	Drawing reference number	Junction detail
1	1076 AA(0) 100	Ground floor/ External wall (Ψ)
2	1076 AA(0) 200	Standard corner (Ψ)
3	1076 AA(0) 301	Intermediate floor/ External wall (Ψ)
4	1076 AA(0) 400	Eaves (room in roof) (Ψ)
5	1076 AA(0) 401	Gable (Ψ)
6	1076 AA(0) 401	Ridge (Ψ)
7	1076 AA(0) 500	Head (Ψ)
8	1076 AA(0) 500	Sill (Ψ)
9	1076 AA(0) 500	Jamb (Ψ)
10	1076 AA(0) 100	3D Ty Unnos vertical beam/ ground floor connection (χ)
11	Burroughs box beam connections	3D Ty Unnos beam ‘connecting pin’ junction (χ)

Figure 1: Diagram of junctions modelled for the Ty Unnos demonstration house



1.1 Modelling software and protocols

This thermal bridging modelling has been done using Physibel's Trisco (v12) software, and following the conventions and guidance in BR497, 'Conventions for calculating linear thermal transmittance and temperature factors' (Ward. T & Sanders. C, 2007).

The temperature factor (f_{Rsi}) for each junction is also quoted. To limit the risk of surface condensation or mould growth at junctions the temperature factor should be greater than or equal to a critical value (f_{CRsi}) of 0.75, as quoted in BRE's Information Paper 1/06, 'Assessing the effects of thermal bridging at junctions and around openings' (Ward. T, 2006).

1.2 Assumptions and use of this bridging data

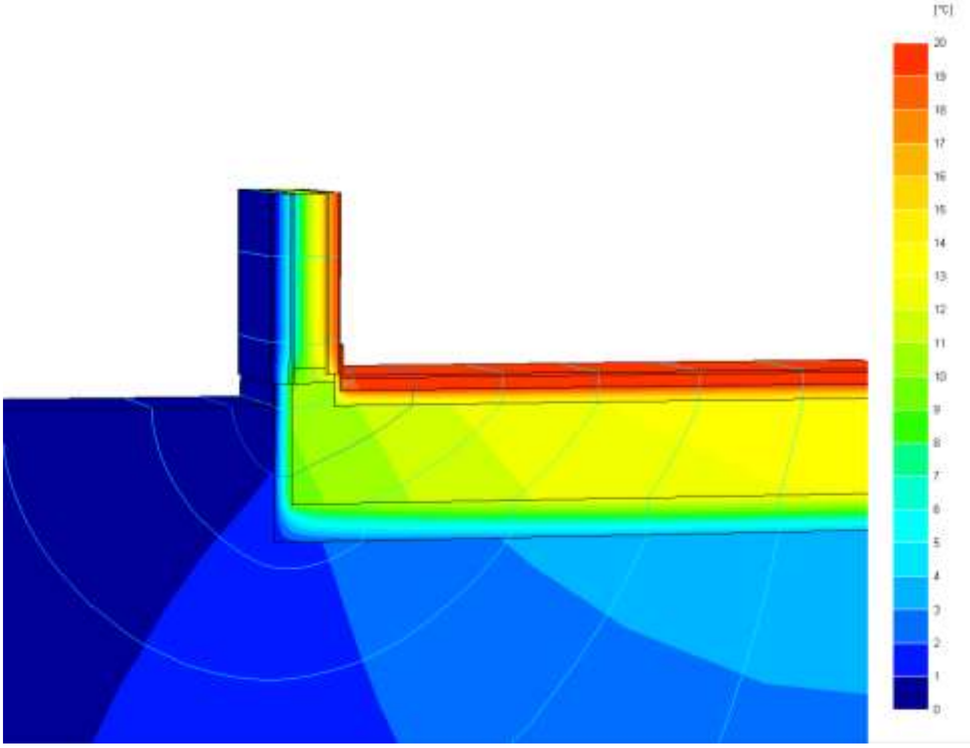
Information about products and materials used have been provided by the architect and thermal conductivity values sought from manufacturers literature wherever possible. In the absence of manufacturer data, generic thermal conductivity values have been used. All relevant material properties associated with the modelling of the various junctions are given together with the calculated results for each detail. If the materials to be used during construction differ from these listed materials such that their thermal properties are different then the calculated ψ-values etc. contained in this report will be invalid. Any change in material properties will require the particular detail(s) to be re-modelled and a new ψ-value determined.

For a particular building the ψ-values will need to be multiplied by the length over which the particular junction applies. For example, a thermal bridge calculated at an intermediate floor will need to be multiplied by the perimeter length of the floor; a thermal bridge calculated at a window head will need to be multiplied by the length of the window head and so on. The number of occurrences of any point thermal bridge would need to be totalled and multiplied by the appropriate χ-value, which gives the total heat loss through these point thermal bridges in W/K.

2 Linear thermal transmittance (ψ) results

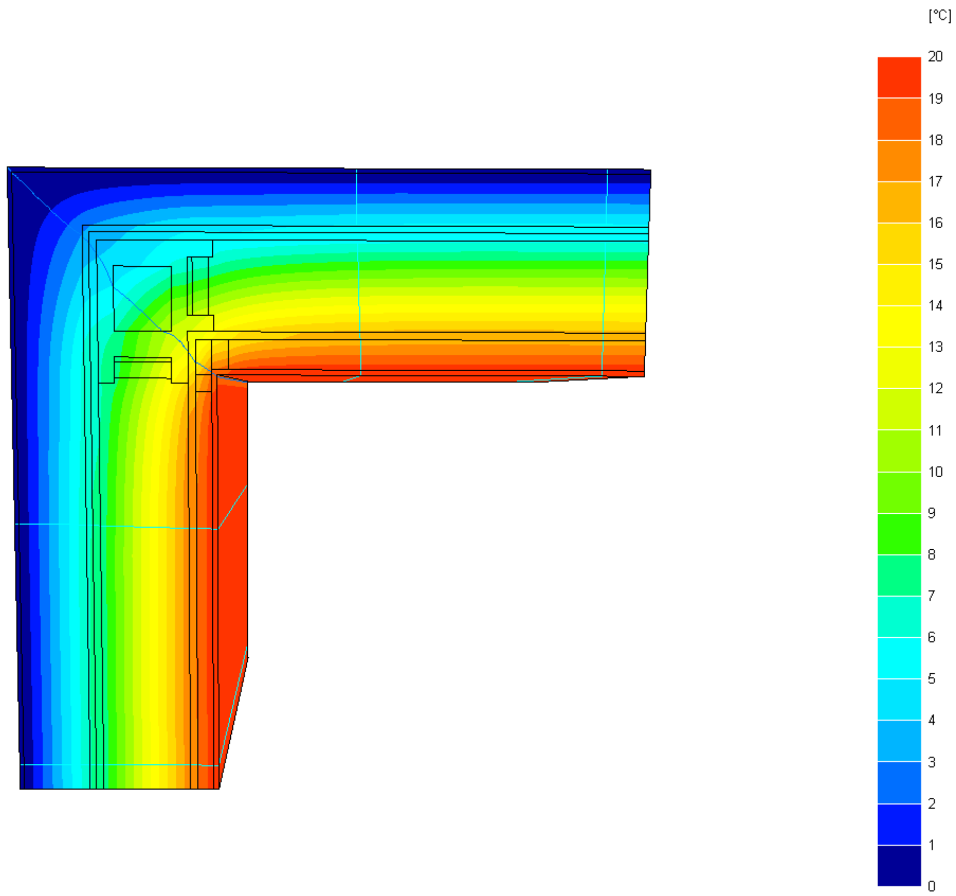
1 Ground floor/ External wall junction

Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Timber sole plate	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
12.5mm plasterboard	0.230	BR 443
Timber skirting board	0.130	BR 443
Hardwood timber floor	0.180	BR 443
Concrete screed	1.350	BS 10455
Concrete slab	1.350	BS 10455
Celotex PIR insulation	0.022	Manufacturer literature
XPS under slab insulation	0.029	Manufacturer literature
Ground	1.500	BS 10455
UK ψ-value	**0.092 W/m·K**	**(E5 - default 0.320 W/m·K)**
Passivhaus ψ-value	**0.043 W/m·K**	
Temperature factor	**0.958**	



2 Standard corner

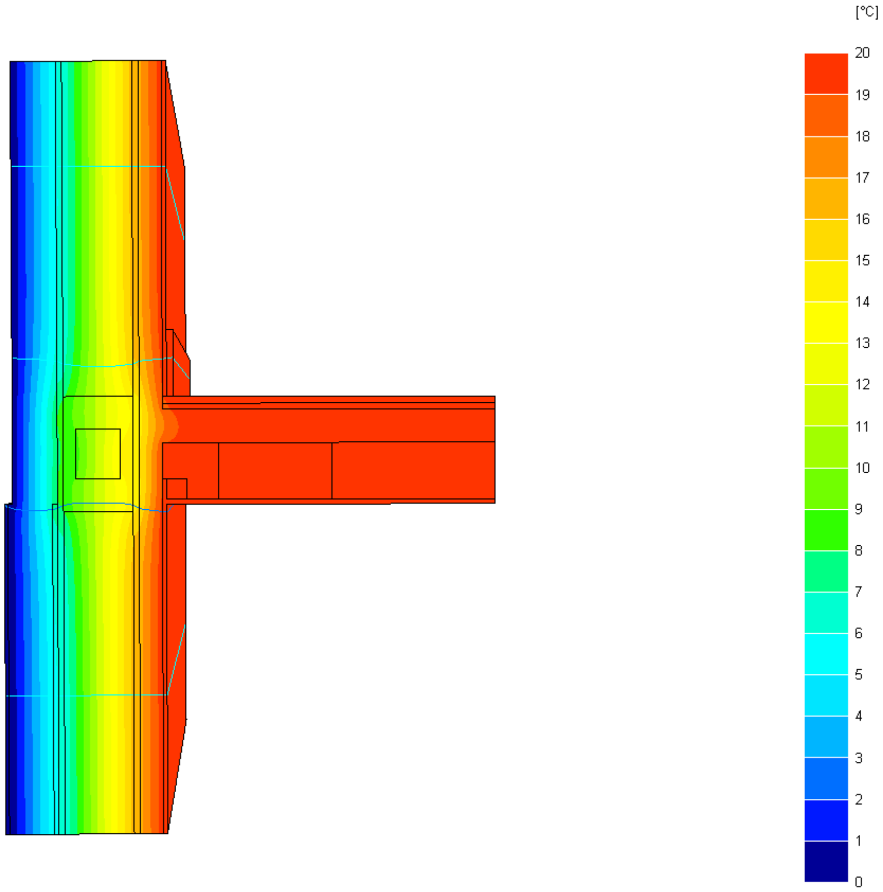
Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
12.5mm plasterboard	0.230	BR 443
Equivalent ladder beam	0.055	Separately modelled
UK ψ-value	**0.041 W/m·K**	**(E16 - default 0.180 W/m·K)**
Passivhaus ψ-value	**-0.042 W/m·K**	
Temperature factor	**0.933**	



3 Intermediate floor/ External wall junction

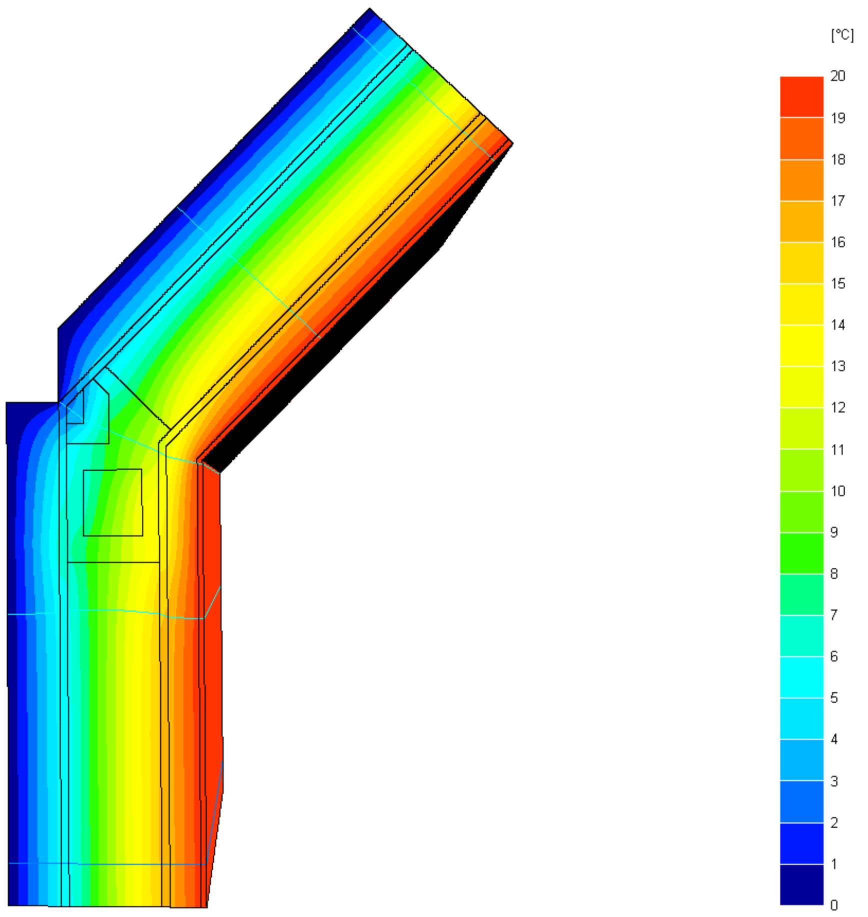
Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
12.5mm & 15mm plasterboard	0.230	BR 443
Timber skirting board	0.130	BR 443
Hardwood timber floor	0.180	BR 443
Ceiling void 1, 170x170mm	0.747	Calculated to BS6946
Ceiling void 2, 170x340mm	1.376	Calculated to BS6946
Ceiling void 3 (same as 2)	1.376	Calculated to BS6946
UK ψ-value	**0.014 W/m·K**	**(E7 - default 0.140 W/m·K)**

Passivhaus ψ-value	**0.014 W/m·K**	
Temperature factor	**0.975**	



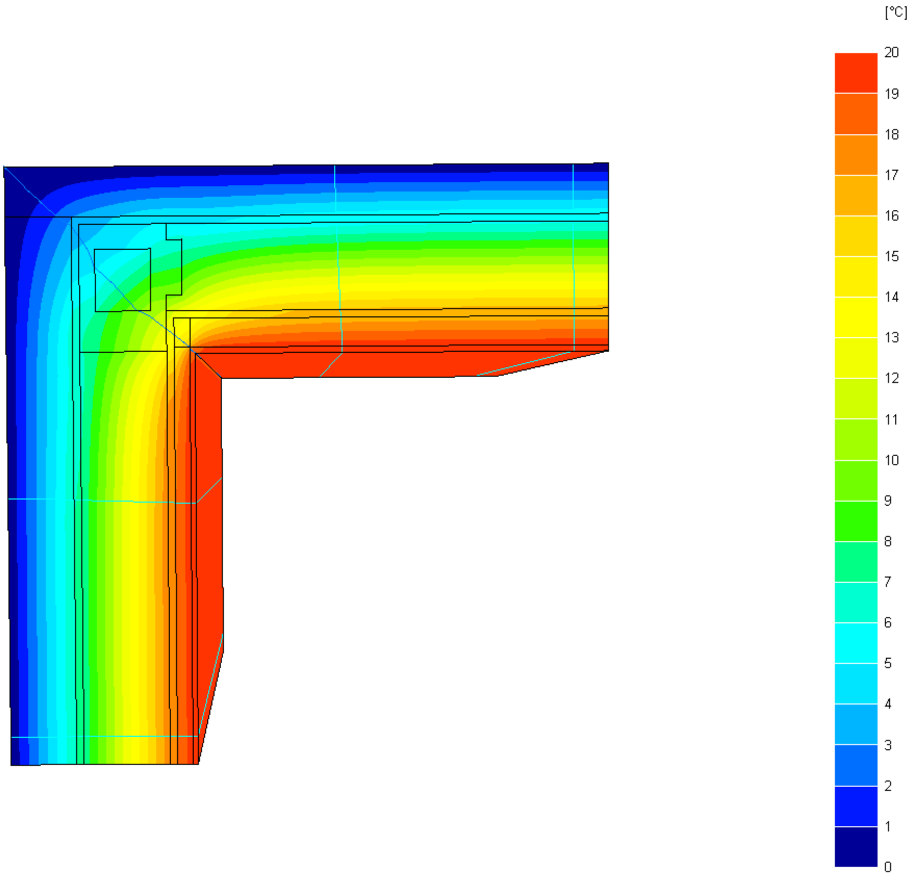
4 Eaves (room in roof) detail

Material	Conductivity W/m·K	Data source/ reference
Rockwool insulation	0.040	Manufacturer literature
Gutex wood fibre insulation	0.039	Manufacturer literature
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
12.5mm & 15mm plasterboard	0.230	BR 443
UK ψ-value	**0.037 W/m·K**	**(E11 - default 0.080 W/m·K)**
Passivhaus ψ-value	**0.004 W/m·K**	
Temperature factor	**0.972**	



5 Gable (room in roof) detail

Material	Conductivity W/m·K	Data source/ reference
Gutex wood fibre insulation	0.039	Manufacturer literature
OSB	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Rockwool insulation	0.040	Manufacturer literature
12.5mm &15mm plasterboard	0.230	BR 443
UK ψ-value	**0.038 W/m·K**	**(E13 - default 0.080 W/m·K)**
Passivhaus ψ-value	**-0.041 W/m·K**	
Temperature factor	**0.941**	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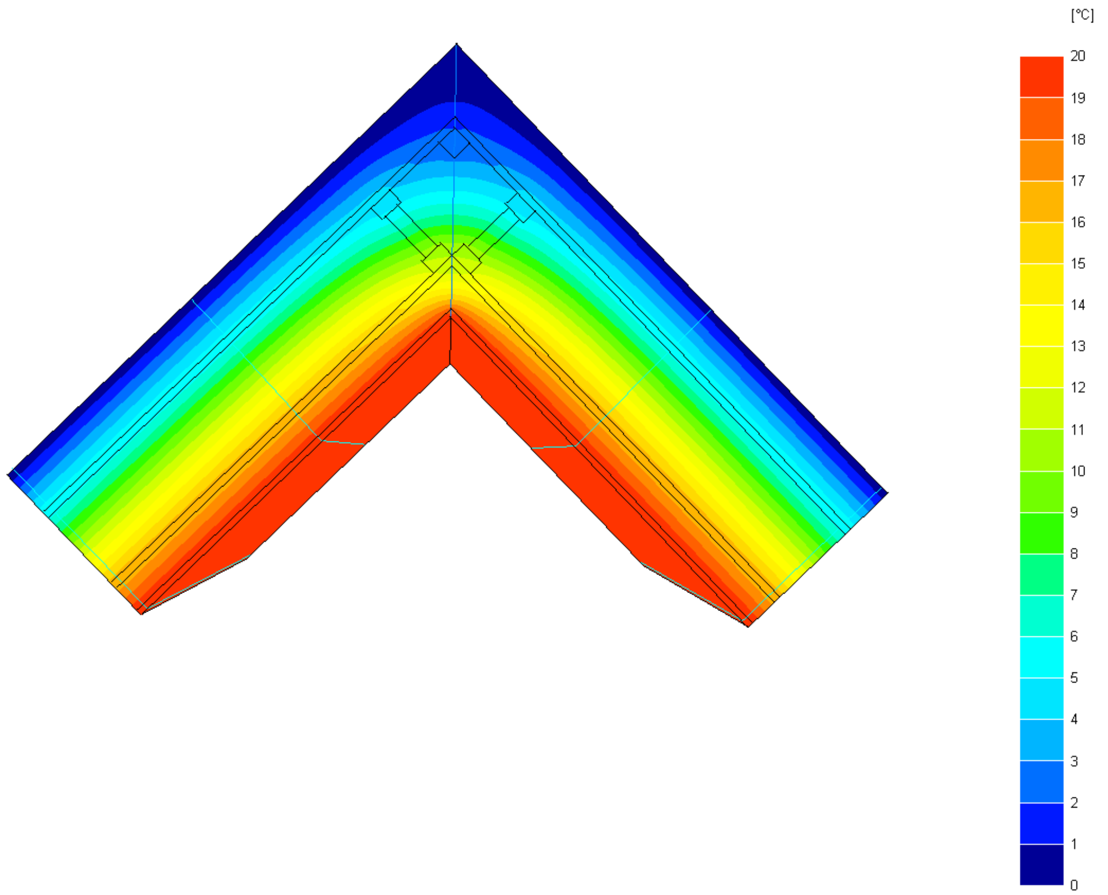
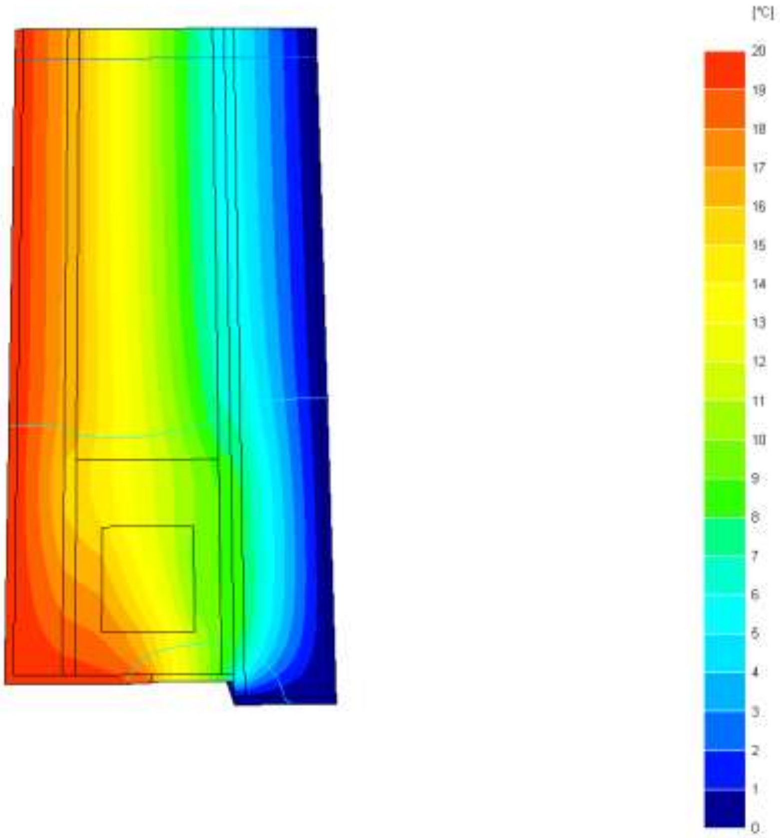
6 Ridge detail

Material	Conductivity W/m·K	Data source/ reference
Gutex wood fibre insulation	0.039	Manufacturer literature
OSB	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
Timber battens	0.130	BR 443
Rockwool insulation	0.040	Manufacturer literature
15mm plasterboard	0.230	BR 443
Equivalent ladder beam	0.060	Separately modelled
UK ψ-value	**0.028 W/m·K**	**(no default)**
Passivhaus ψ-value	**-0.052 W/m·K**	
Temperature factor	**0.963**	



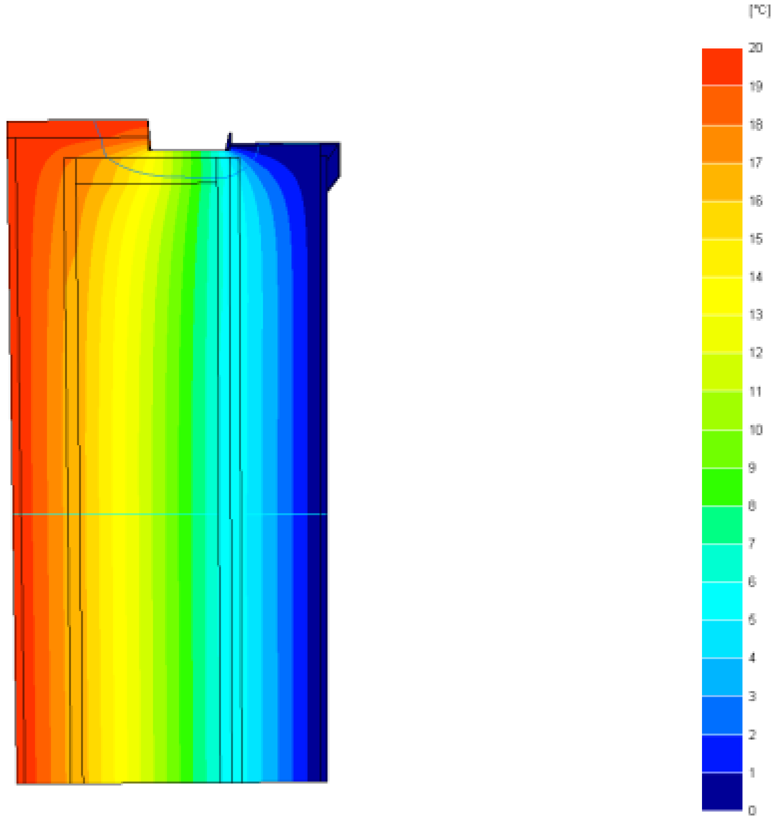
7 Head detail

Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel fibre insulation	0.035	Manufacturer literature
12.5mm plasterboard	0.230	BR 443
Modelled ψ-value	**0.038 W/m·K**	**(E2 default 1.000 W/m·K)**
Temperature factor	**0.923**	



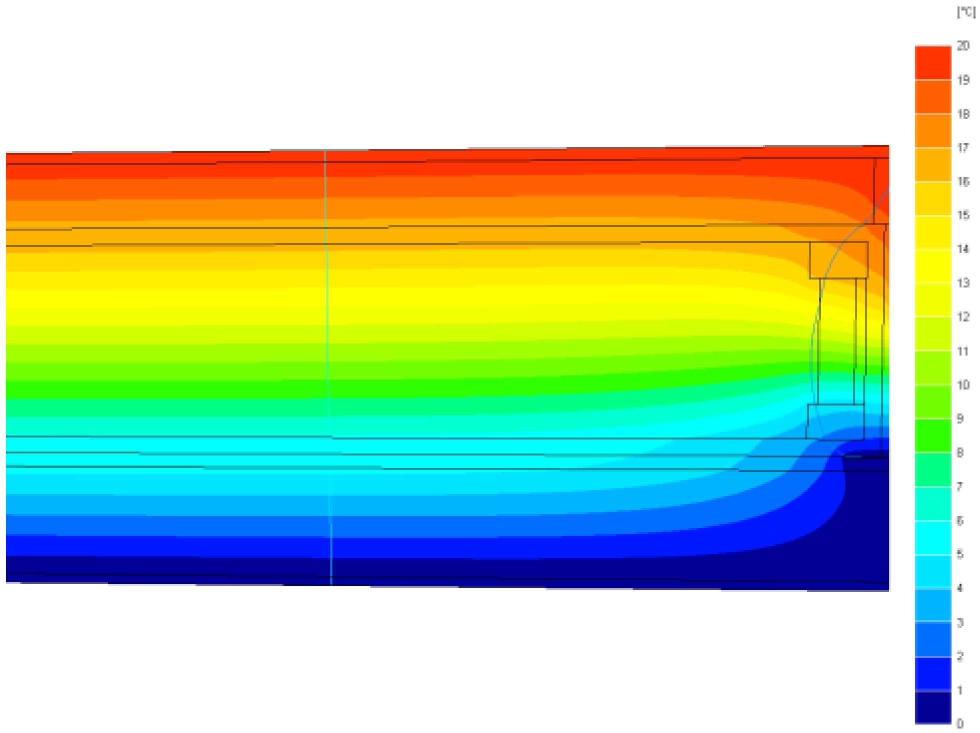
8 Sill detail

Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel fibre insulation	0.035	Manufacturer literature
12.5mm plasterboard	0.230	BR 443
Aluminium window sill	160.00	BS 10455
Hardword sill board	0.180	BR 443
Modelled ψ-value	**0.014 W/m·K**	**(E3 default 0.080 W/m·K)**
Temperature factor	**0.963**	



9 Jamb detail

Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel fibre insulation	0.035	Manufacturer literature
12.5mm plasterboard	0.230	BR 443
Aluminium reveal lining	160.00	BS 10455
Modelled ψ-value	**0.023 W/m·K**	**(E4 default 0.100 W/m·K)**
Temperature factor	**0.963**	

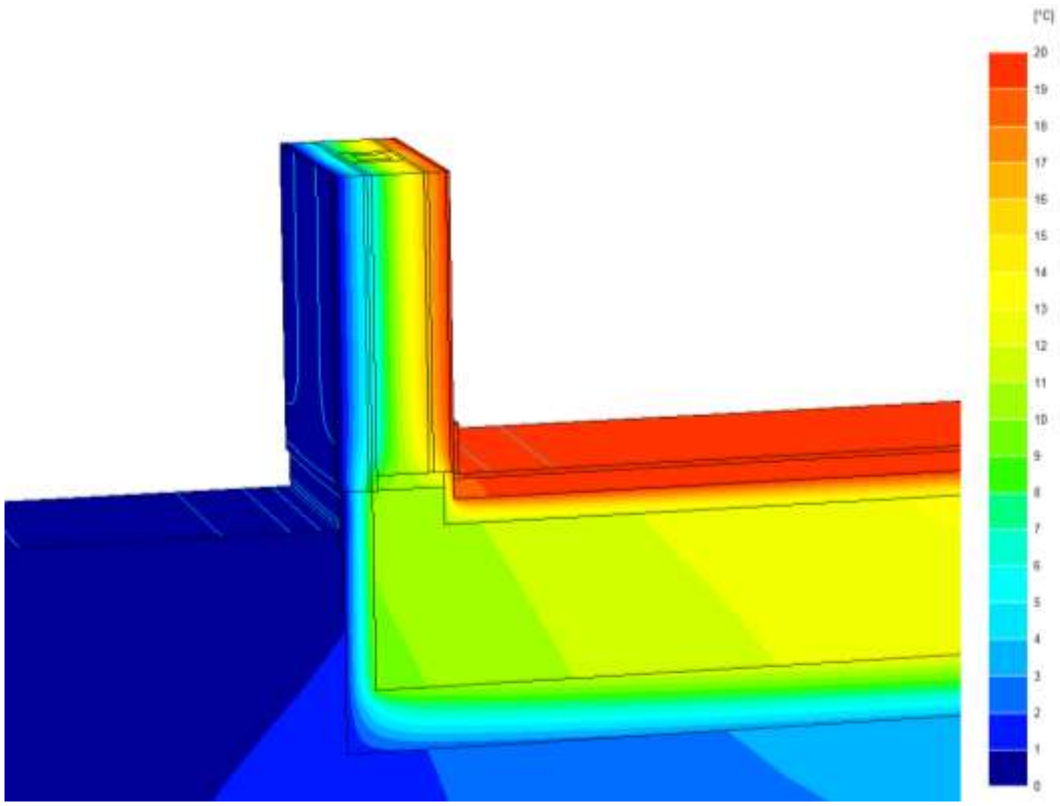


NB: The aluminium reveal lining used in this detail has a notable affect on the resulting ψ-value quoted here, since aluminium is a highly conductive material. If the aluminium lining were not present and the reveal instead rendered the resulting ψ-value would be closer to 0.014 W/m·K.

3 Point thermal transmittance (χ) results

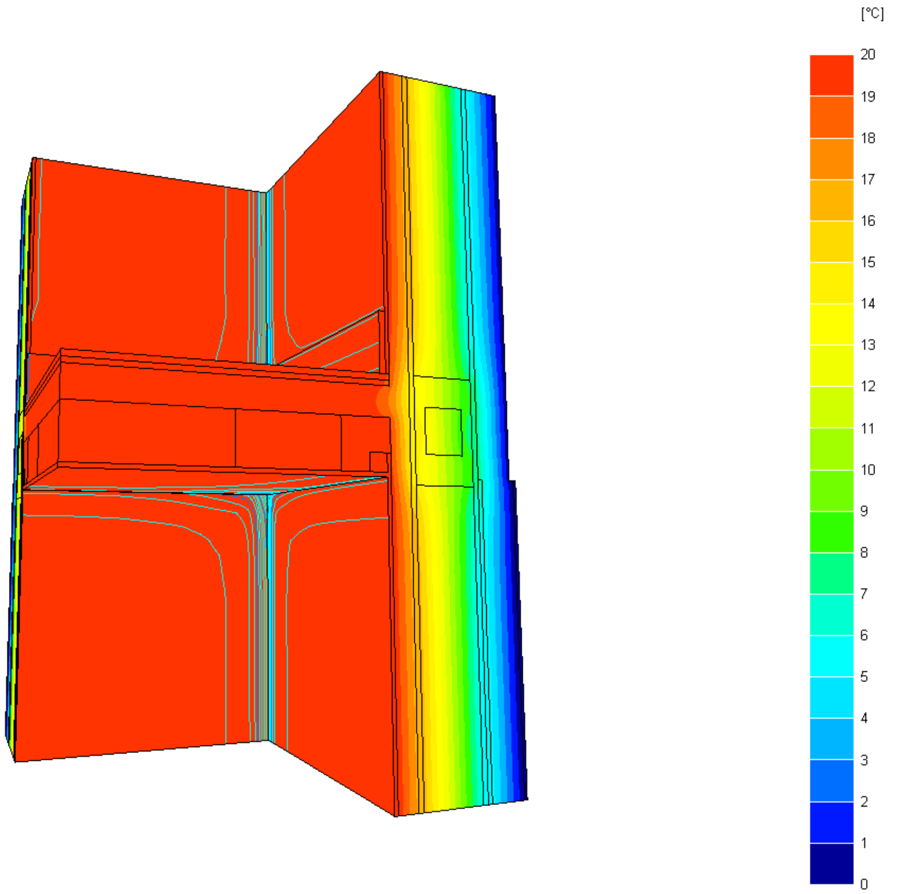
10 3D Ty Unnos vertical beam/ ground floor connection

Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Timber sole plate	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
12.5mm plasterboard	0.230	BR 443
Timber skirting board	0.130	BR 443
Hardwood timber floor	0.180	BR 443
Concrete screed	1.350	BS 10455
Concrete slab	1.350	BS 10455
Celotex PIR insulation	0.022	Manufacturer literature
XPS under slab insulation	0.029	Manufacturer literature
Ground	1.500	BS 10455
Ty Unnos beam	0.130	BR 443
Galvanised steel reinforcements	50.00	BR 443
χ-value	**0.014 W/K**	**Assume 12no such connections in demonstration house**



11 3D Ty Unnos beam ‘connecting pin’ junction (4 direction pin)

Material	Conductivity W/m·K	Data source/ reference
External render	1.000	BS 10455
Rockwool insulation	0.040	Manufacturer literature
15mm cavity void	0.088	Calculated to BS6946
OSB	0.130	BR 443
Ty Unnos beam	0.130	BR 443
Timber battens	0.130	BR 443
Warmcel blown fibre insulation	0.035	Manufacturer literature
12.5mm & 15mm plasterboard	0.230	BR 443
Timber skirting board	0.130	BR 443
Hardwood timber floor	0.180	BR 443
Ceiling void 1, 170x170mm	0.747	Calculated to BS6946
Ceiling void 2, 170x340mm	1.376	Calculated to BS6946
Ceiling void 3 (same as 2)	1.376	Calculated to BS6946
Galvanised steel reinforcements	50.00	BR 443
Equivalent ladder beam	0.055	Separately modelled
χ-value	**0.009 W/K**	



The connecting pin modelled was a 4 direction pin; locking the Ty Unnos beams into place from above and below and in each direction into the intermediate floor beams, giving a χ-value of 0.009 W/K. In order to provide indicative values for 2, 3 or 5 direction pins, it is proposed that the contribution of the pins from the above model are allocated proportionally to the number of pins in question, i.e. 0.00225 W/K per pin. Hence for:

- 2 pins, assume 0.0045 W/K per connecting pin
- 3 pins, assume 0.0068 W/K per connecting pin
- 5 pins, assume 0.0113 W/K per connecting pin.

In the demonstration house, it is assumed that there are 6 x 2 pin connections, 8 x 4 pin connections and 16 x 5 pin connections, which would contribute to the overall heat loss of the building in addition to that represented by the U values and the ψ-values, as indicated in Table 2.

3.1 Sum of the energy loss attributable to the χ-values in the demonstration house

Table 2: Contribution each of the point bridges will make to the overall energy demand of the demonstration house

Point bridge	Number of occurrences in demonstration house	χ W/K	Sum total W/K
Ground floor connection	12	0.0140	0.168
2 pin connections (at roof ridge)	6	0.0045	0.027
4 pin connections (at intermediate floor corners and gable corners)	8	0.0090	0.072
5 pin connections (at repeating intermediate floor beams and repeating beams at eaves level)	16	0.0113	0.181
		Total	**0.448**

4 Discussion

Since the combination of U values, ψ-values and χ-values should represent the total heat loss from the building, it is important that the U values used when assessing the building are calculated appropriately relative to how these ψ-and χ-values have been calculated. The U values should account for the contribution from the repeating bridging that occurs at the intermediate Ty Unnos structural beams (those not at the junctions), in addition to the repeating bridging from ladder 'cross beams' present. An example U value calculation for the wall has been calculated in Table 3.

The bridging effect of the ladder beams within the timber frame panels has been reported by the designer to offset a 10% proportion of the insulation of the plane elements. This is represented in lines 5a, 6a and 7a in the U value calculation in Table 3. However the repeating intermediate Ty Unnos beams (those highlighted in Figure 2) form additional bridges that are not included within this 10%. The overall length of the building is 12.66m and there are 4 intermediate beams that are not accounted for by the ψ-values modelled for this report. The timber within the Ty Unnos beams, as shown in Figure 3, is therefore divided by this overall length to provide a percentage contribution to the overall per m^2 U value of the wall in lines 5b, 6b and 7b of Table 3.

Figure 2: Intermediate repeating Ty Unnos beams not represented by the reported ψ-values

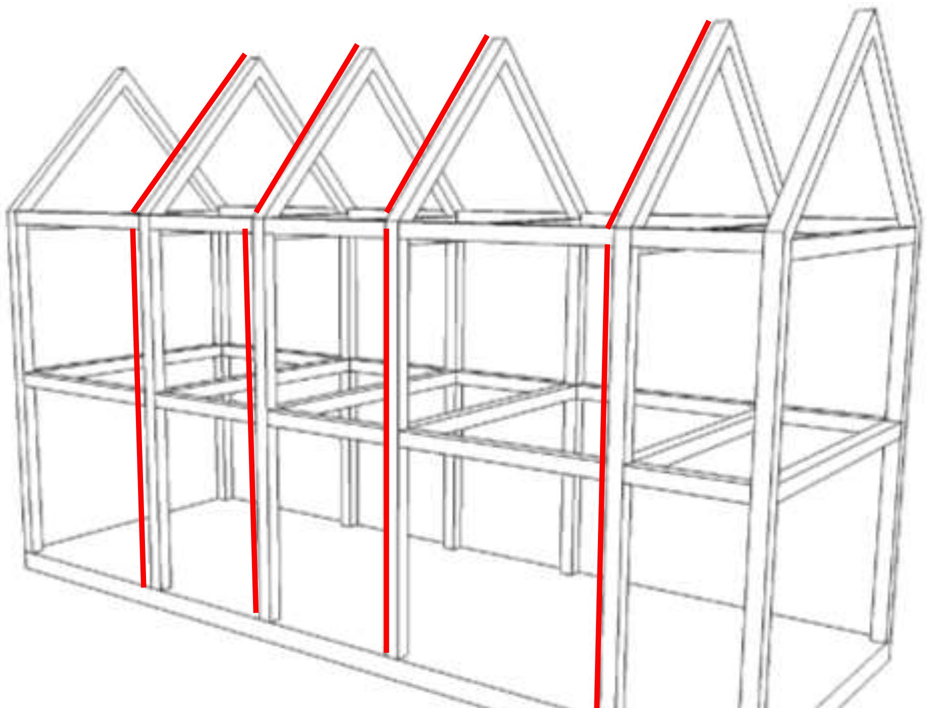


Figure 3: Simple representation of the cross section of a Ty Unnos beam within the wall

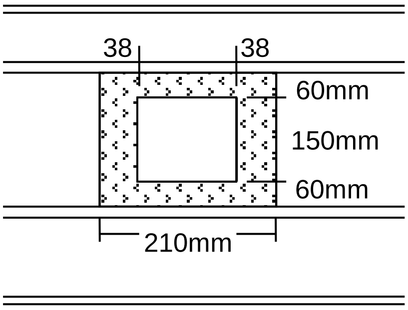


Table 3: Example calculation of Wall U value (using BRE U value calculator tool)

Layer	depth (mm)	λ layer	λ bridge	Fraction	R layer	R bridge	Description
					0.130		Rsi
1	12.5	0.230			0.054		Plasterboard
2	60.0	0.040	0.130	0.100	1.500	0.462	Mineral wool
3							Vapour control layer
4	18.0	0.130			0.138		OSB
5a	60.0	0.035	0.130	0.100	1.714	0.462	insulation/ timber ladder stud
5b			0.130	0.066		0.462	insulation/ Ty Unnos beam 60mm
6a	150.0	0.035	0.130	0.100	4.286	1.154	insulation/ timber ladder stud
6b			0.130	0.024		1.154	insulation/ Ty Unnos beam 150mm
7a	60.0	0.035	0.130	0.100	1.714	0.462	insulation/ timber ladder stud
7b			0.130	0.066		0.462	insulation/ Ty Unnos beam 60mm
8	18.0	0.130			0.138		OSB
9	125.0	0.040			3.125		Rainscreen slab
10	10.0	1.000			0.010		Render
					0.040		Rse

Total resistance: Upper limit: 11.781 Lower limit: 10.431 Ratio: 1.129 Average: 11.106 m²K/W			
U-value (uncorrected)		0.090	W/m²K
U-value corrections			
Air gaps in layer 6	ΔU = 0.001	(Level 1)	
Fixings in layer 9	ΔU = 0.002	(2.50 per m², 101.0 mm² cross-section, l = 17.0)	
Total ΔU	0.003		
U-value (corrected)		**0.093**	**W/m²K**

4.1 Use of χ-values in SAP or PHPP for Passivhaus

The presence of the connecting elements that have been modelled to provide χ-values is not readily captured in SAP 2009 or PHPP for Passivhaus assessments. χ-values are point bridges that do not have a 'length' as such. While it would be very easy to dismiss the effect of these point bridges, this modelling indicates that, due to the nature of the connections for the Ty Unnos structural beams, the U values and ψ-values alone would underestimate the energy demand of the building by 0.448 W/K. To put this into perspective, the energy loss associated with the ψ-value of the perimeter length of the intermediate floor junction would be 0.472 W/K for the demonstration house.

In order to include the relevant χ-values in either a SAP calculation or in PHPP, it is suggested that the sum of the number of instances of any particular χ-values present are expressed as an equivalent ψ-or U value in such a way that it can be entered into the SAP or PHPP calculation, as shown in Figure 4 and Figure 5. Since χ-has units of W/K, when entered either as a ψ-value or U value the length or area are entered as 1m or 1m^2 respectively. The product of either ψ x l or U x A thus give the W/K associated with these point thermal bridges.

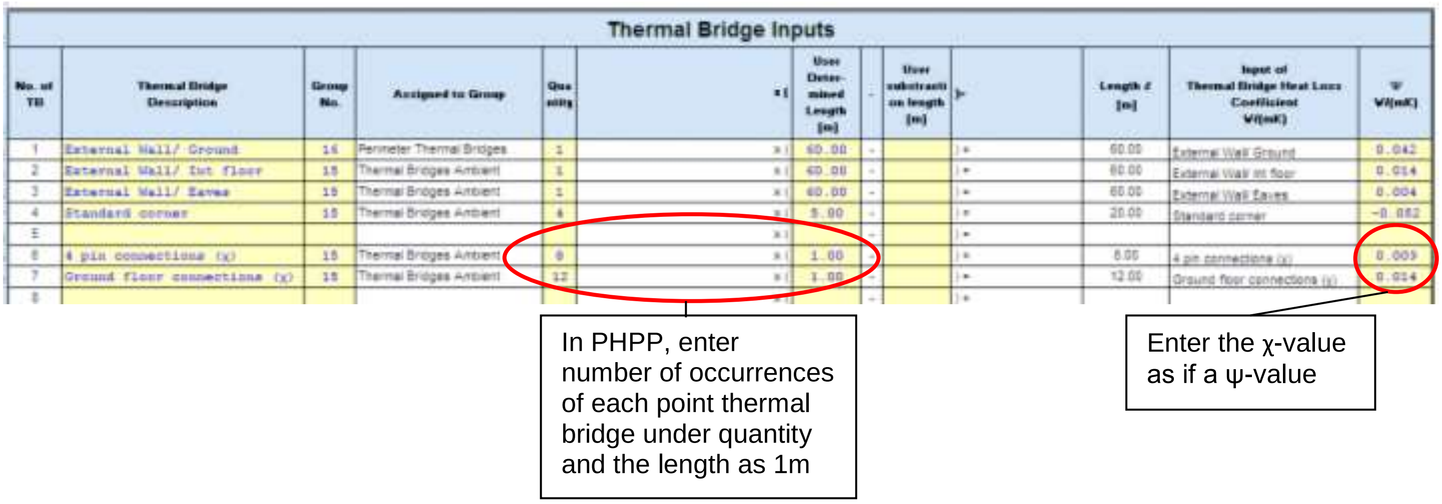
Figure 4: Example of entering χ-values as equivalent U values in SAP

Exposed areas (m²) and U-values (W/m²K)

Element	Gross area	Openings	Net Area	U-value	kappa
Ground floor (1)			50.00	0.15	
Ground floor (2)					
Exposed floor					
Walls (1)	100.00	22.42	77.58	0.13	
Walls (2)	12.00		12.00	0.014	
Walls (3)	16.00		16.00	0.011	
Walls (4)					
Roof (1)	50.00		50.00	0.13	
Roof (2)					
Roof (3)					
Roof (4)					
Exposed side wall					
Party wall				0	
Party ceiling					
Internal wall (1)					
Internal wall (2)					
Internal wall (3)					

In SAP, enter number of occurrences of point thermal bridge as if an 'area' and the χ-value as if a 'U value'

Figure 5: Example of entering χ-values as equivalent ψ-values in PHPP



Thermal Bridge Inputs												
No. of TB	Thermal Bridge Description	Group No.	Assigned to Group	Quantity	x (	User Determined Length [m]	-	User substraction on length [m]	) =	Length ℓ [m]	Input of Thermal Bridge Heat Loss Coefficient W/(mK)	Ψ W/(mK)
1	External Wall/ Ground	16	Perimeter Thermal Bridges	1	x (	60.00	-		) =	60.00	External Wall Ground	0.042
2	External Wall/ Int floor	15	Thermal Bridges Ambient	1	x (	60.00	-		) =	60.00	External Wall Int floor	0.014
3	External Wall/ Eaves	15	Thermal Bridges Ambient	1	x (	60.00	-		) =	60.00	External Wall Eaves	0.004
4	Standard corner	15	Thermal Bridges Ambient	4	x (	5.00	-		) =	20.00	Standard corner	-0.062
5					x (		-		) =			
6	4 pin connections (χ)	15	Thermal Bridges Ambient	8	x (	1.00	-		) =	8.00	4 pin connections (χ)	0.003
7	Ground floor connections (χ)	15	Thermal Bridges Ambient	12	x (	1.00	-		) =	12.00	Ground floor connections (χ)	0.014
8					x (		-		) =			

4.2 Comparison of modelled ψ-values with the default ψ-values in SAP 2009

Within the tables in the previous section, the calculated ψ-values for each junction detail are compared with the default values in SAP. The defaults would need to be used where there is no modelled bespoke ψ-value available. It can be seen that the modelled junctions have considerably lower ψ-values compared to the defaults, which will benefit the heat loss calculation in SAP.

4.3 Use of ψ-values for Passivhaus PHPP modelling

In general, the aim within a Passivhaus is for 'thermal bridge free' design, which is defined as ψ-values of less than 0.01 W/m·K, where for Passivhaus external dimensions are used when determining the heat transfer coefficients. Many of the junctions modelled for this study have (under Passivhaus) ψ-values less than 0.01 W/m·K and indeed some have negative ψ-values. However other junctions, for example the ground floor/ external wall junction and intermediate floor/ external wall junction exceed this target, so these ψ-values would therefore need to be included in the Passivhaus PHPP assessment. It would in fact be worthwhile to include the negative ψ-values within the PHPP analysis, as they will actually reduce the overall energy demand from the Passivhaus heat loss calculation.