THERMAL BRIDGING GUIDE

An introductory guide to thermal bridging in homes

CONTACTS

Further copies of this guide are available as a PDF download from **www.zerocarbonhub.org**

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ACKNOWLEDGEMENTS

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CONTENTS

The Technical Annex can be found in the electronic version of this Guide available at www.zerocarbonhub.org

INTRODUCTION

This document provides a simple guide to what thermal bridging is, the key construction details in new build housing where thermal bridging is particularly significant, examples of ways in which heat loss can be reduced by changes to the design and construction of these details, and the problem areas to avoid on site.

It is intended to help designers and builders focus on the key decisions that they can affect around junction detailing which will have a direct bearing on the performance of the new homes they help to deliver.

This Guide begins with a few explanatory pages describing what thermal bridges are and how their effects are quantified.

Key construction details are then illustrated for both masonry and timber frame construction showing how their thermal performance can either be improved or compromised by adopting alternative construction details, material specifications or site practices. This is the main part of the document.

The electronic version of this Guide also contains an Annex aimed at those who would like further information, covering: general principles to improve junction performance, the benefits in SAP of improved junction details, illustrated guidance to identify all relevant linear thermal bridges, how to establish the key junctions for a particular dwelling type, and a summary of the results of the PSI-value modelling work carried out for this Guide.

Please Note

⚠ **The details drawn in this Guide are for illustrative purposes only and should not be used as working drawings.** For example, consideration must also be given to structure, waterproofing, airtightness, general good practice and sequencing on site.

⚠ **The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations.**

Various sources exist to obtain PSI-values for the building junctions of interest, as follows:

- Generic industry sponsored libraries covering the common building types e.g. LABC (http://www.labc.co.uk/registration-schemes/construction-details) or Scottish Standards (http://www.gov.scot/Topics/Built-Environment/Building/Building-standards/publications/pubtech)
- Individual product or building system manufacturer sponsored libraries, covering specific building products/systems.
- Bespoke PSI-values calculated by 'competent persons' for specific developments.

UNDERSTANDING THE DETAIL PAGES

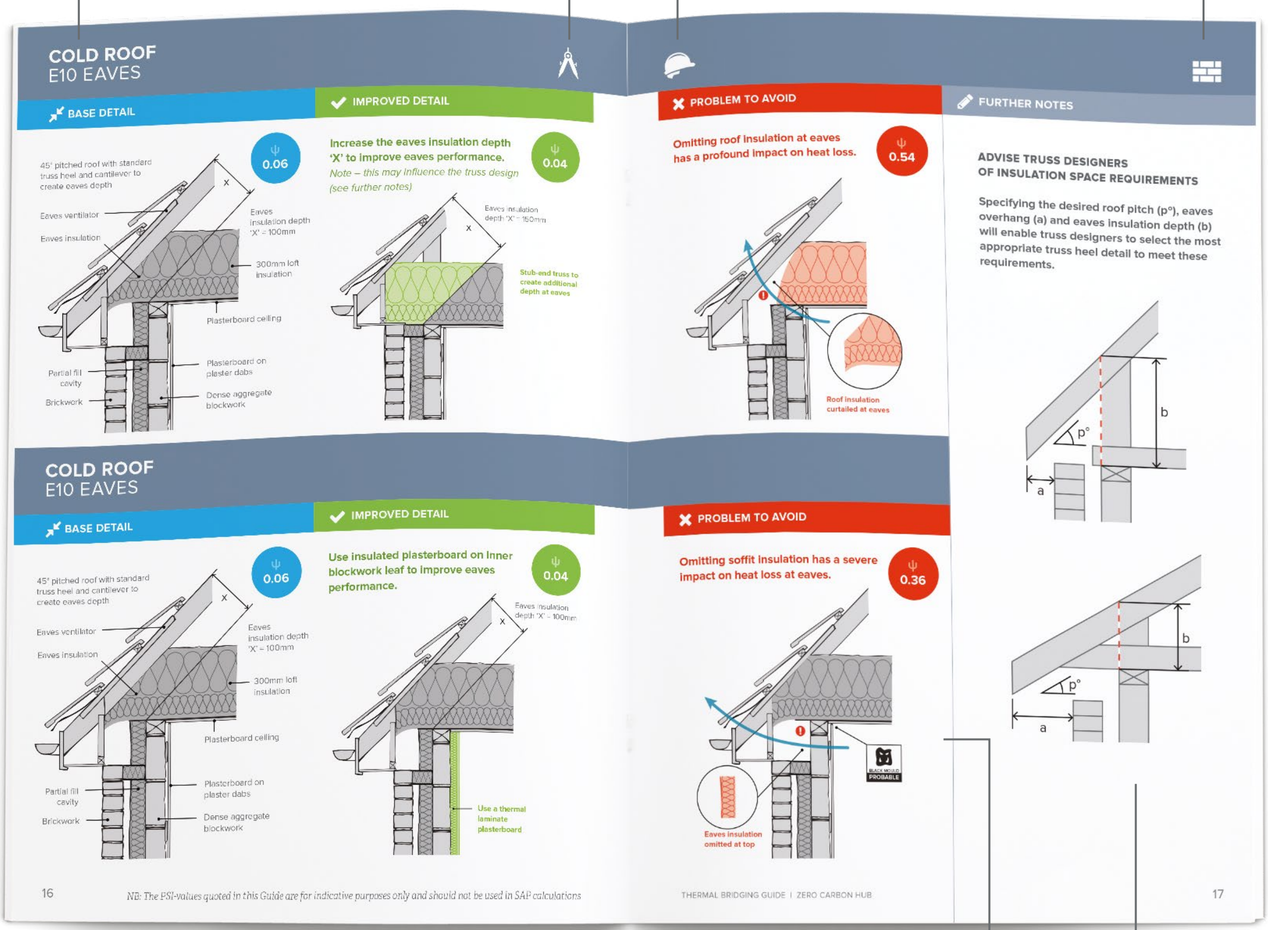
Construction type:

Masonry

Timber Frame

Construction detail type (with SAP Table K1 reference)

Primary responsibility:
Designer Builder



Blue themes = base construction (assumed starting point)

Green themes = possible design improvements

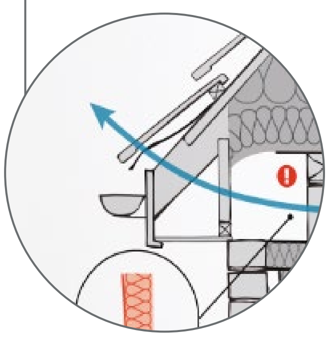
Red themes = problem areas to be avoided and checked on site

Additional useful information

Guide PSI-values are displayed in theme coloured circles

For indicative purposes only, black mould risk is identified where this becomes a likely consequence of problem details

Heat loss path illustrated by blue arrows



WHAT ARE THERMAL BRIDGES?

A thermal bridge (sometimes called a cold bridge) is a localised weakness or discontinuity in the thermal envelope of a building. They generally occur when the insulation layer is interrupted by a more conductive material.

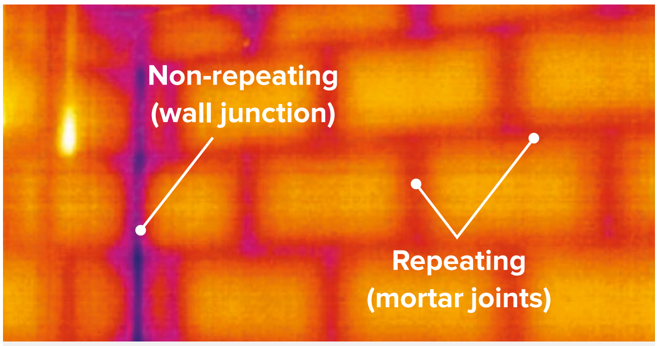
The type of thermal bridges considered in this Guide are called non-repeating or linear thermal bridges. These occur at junctions between elements, such as a wall and a floor or a window and a wall. At these locations heat is more able to transfer through the construction, resulting in greater heat loss from the dwelling and localised 'cold spots' in the building envelope.

Improving junction details to reduce linear thermal bridging will help achieve Building Regulations compliance and is one component in achieving healthy low energy homes.

THE EFFECTS OF THERMAL BRIDGES

Increased heat loss
Thermal bridges can account for 20-30% of the heat loss in a typical new build home. As homes become better insulated thermal bridges become even more significant.

Localised 'cold-spots'
Sometimes leading to condensation build-up or mould growth.



REPEATING AND NON-REPEATING THERMAL BRIDGES

There are two types of thermal bridges in buildings - repeating and non-repeating thermal bridges.

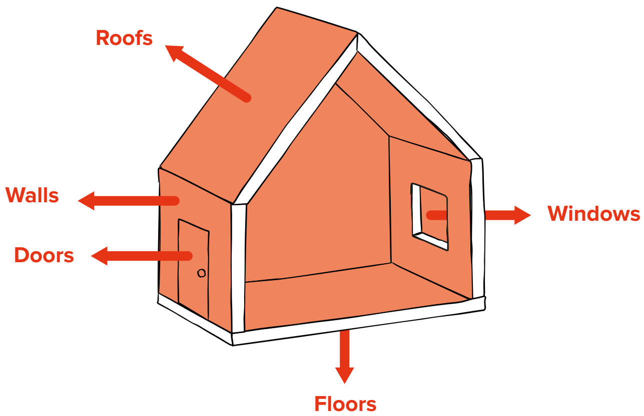
Examples of **repeating** thermal bridges are mortar joints and wall-ties in masonry construction or timber or steel studs in framed construction. Where the frequency of these is known and consistent their effects can be accounted for directly in the U-value calculation for the building element itself.

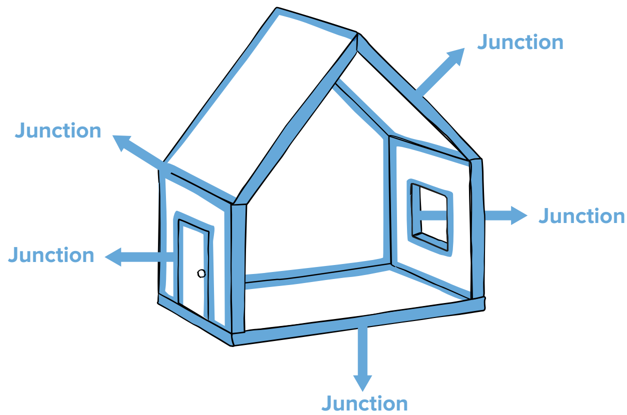
The remaining **non-repeating** thermal bridges are dealt with by "PSI-values" – pronounced 'Si ' (silent p), and designated by the Greek letter 'ψ'. Their effects on heat loss are calculated by thermal modelling software, and they are accounted for separately in SAP calculations in addition to U-values.

KEY JUNCTIONS

Although there are many junctions within a dwelling, some have extremely low PSI-values and others occur over very short lengths. The key junctions to 'get right' or improve are those which either have a high PSI-value or occur frequently over significant lengths. Although the particular junctions of interest will vary depending on dwelling type and design, this Guide covers the key junctions considered by the authors to be the most significant across a range of dwelling types.

HOW IS FABRIC HEAT LOSS QUANTIFIED?





ELEMENT LOSSES

ELEMENT U-VALUES (W/m^2K)

Quantify the heat loss from each of the external building elements such as floors, walls, windows, doors etc. The area of each element multiplied by its **U-value** gives its anticipated heat loss.

THERMAL BRIDGE LOSSES

JUNCTION PSI-VALUES (W/mK) → **DWELLING Y-VALUE (W/m^2K)**

Quantify the heat loss from each of the junctions where the building elements meet (thermal bridges). Multiplying the junction **PSI-value** by the junction length gives the junction heat loss.

The sum of the individual junction heat losses divided by the total exposed surface area of the dwelling gives the **Y-value**. The Y-value expresses the overall heat loss arising from all of the building junctions as an equivalent U-value for the dwelling.

In SAP fabric heat loss is quantified by a combination of U-values and Y-values

ELEMENT LOSSES: U-VALUES x ELEMENT AREAS (70-80% of fabric heat loss)
+
THERMAL BRIDGE LOSSES: Y-VALUE x TOTAL EXPOSED SURFACE AREA (20-30% of fabric heat loss)
=
TOTAL FABRIC HEAT LOSS

Note: Lower U-values, Y-values and PSI-values will result in lower fabric heat loss.

MASONRY CONSTRUCTION

TOP THERMAL BRIDGING TIPS
MASONRY CONSTRUCTION

KEY DESIGN RECOMMENDATIONS

	Design recommendation	No. of junctions affected	Junction references
1	Use a split or thermally broken lintel	1	E2 (page 8)
2	Use light aggregate blockwork inner leaf	4	E5, P1, E12, P4 (pages 12, 14, 18, 20)
3	Use a PU/PIR cavity closer	3	E2, E3, E4 (pages 8, 10)
4	Use insulated plasterboard on the inner leaf	5	E2, E4, E10, E12, P4 (pages 8, 10, 16, 18, 20)
5	Use a window frame overlap of min. 50mm	3	E2, E3, E4 (pages 8, 10)
6	Increase eaves insulation depth	1	E10 (page 16)

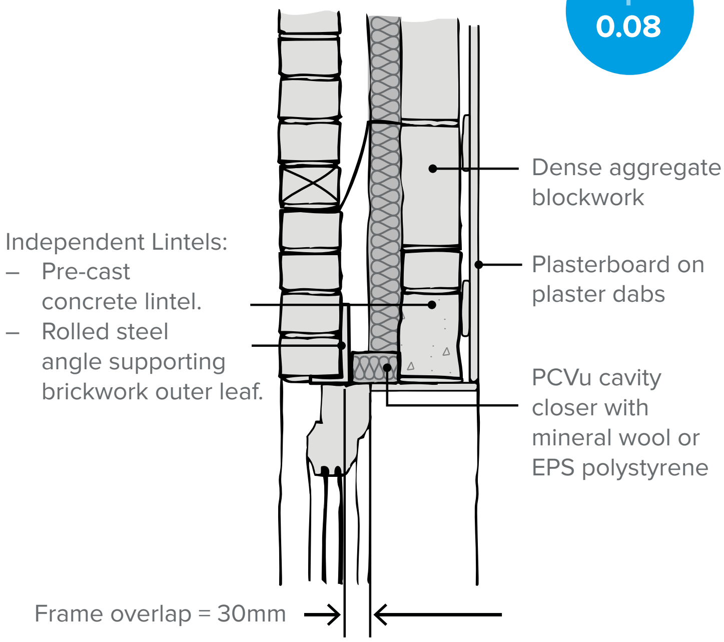
KEY PROBLEMS TO AVOID

	Problem / site check	No. of junctions affected	Junction references	Black mould risk
1	Omitting rafter insulation at eaves	1	E10 (page 16)	
2	Omitting insulation between truss and wall	2	E12, P4 (pages 18, 20)	BLACK MOULD PROBABLE
3	Omitting soffit insulation at eaves	1	E10 (page 16)	BLACK MOULD PROBABLE
4	Stopping party wall cavity insulation short of loft	1	P4 (page 20)	BLACK MOULD POSSIBLE
5	Swapping a split lintel with a perforated steel lintel	1	E2 (page 8)	
6	Omitting the cavity closure	3	E2, E3, E4 (pages 8, 10)	
7	Omitting cavity insulation below DPC	2	E5, P1 (pages 12, 14)	
8	Omitting floor perimeter insulation	2	E5, P1 (pages 12, 14)	BLACK MOULD POSSIBLE
9	No window frame overlap with cavity	3	E2, E3, E4 (page 8, 10)	

INDEPENDENT LINTEL
E2 LINTELS

BASE DETAIL

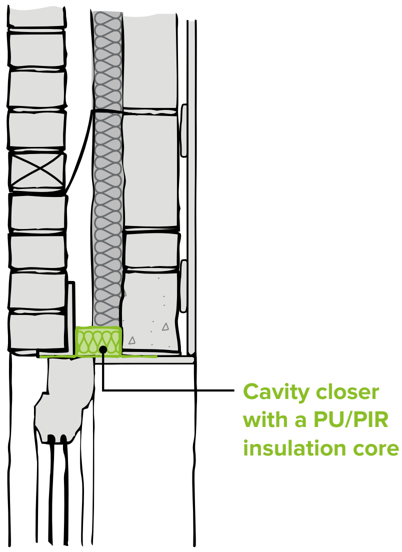
ψ 0.08



IMPROVED DETAIL

Use a cavity closer with a PU/PIR insulation core to improve performance for independent lintels.

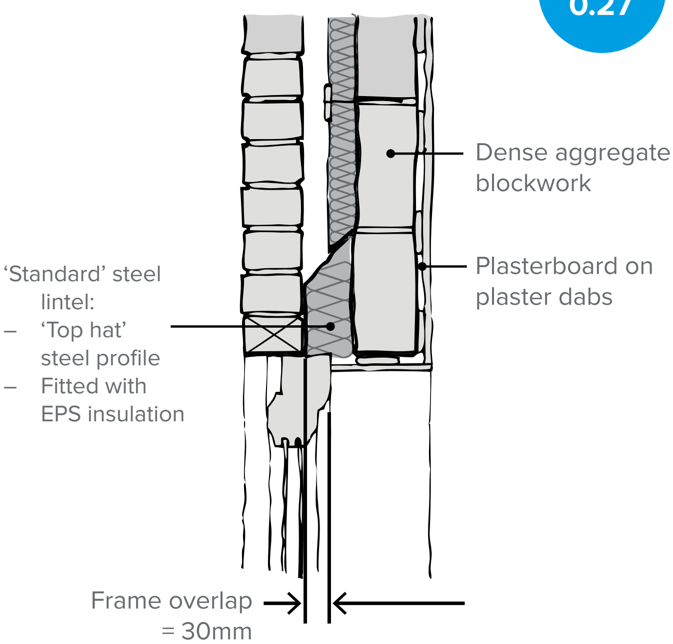
ψ 0.04



PERFORATED STEEL LINTEL
E2 LINTELS

BASE DETAIL

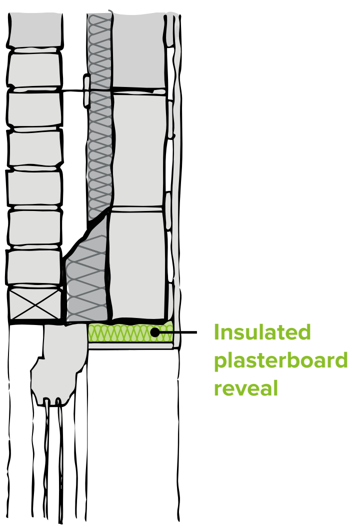
ψ 0.27



IMPROVED DETAIL

Use an insulated plasterboard reveal to improve performance for perforated steel lintels.

ψ 0.21



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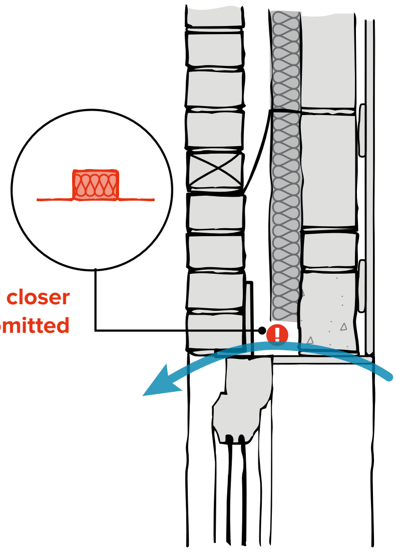
✖ PROBLEM TO AVOID

Omitting the cavity closer makes heat loss significantly worse.

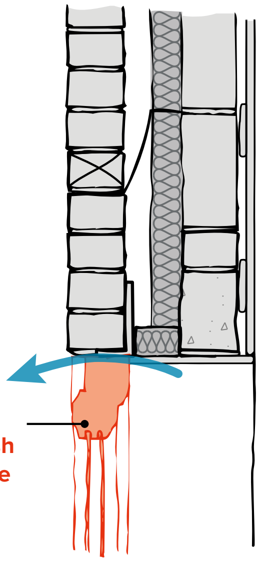
ψ 0.26



✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse.

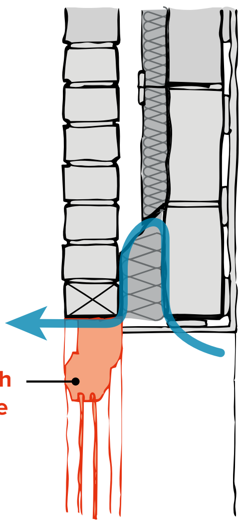
ψ 0.15



✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse.

ψ 0.31



FURTHER NOTES

✔ LINTEL SELECTION

Independent lintels have Ψ-values approximately Ψ = 0.2 lower than perforated steel lintels.

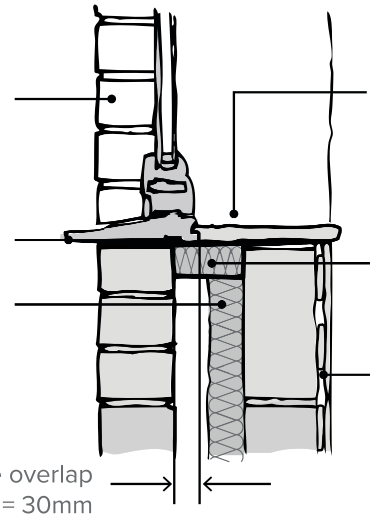
✔ FRAME OVERLAP

Increasing the frame overlap from 30mm to 50mm will also reduce the Ψ-value of lintels, sills and jambs by approximately Ψ = 0.02.

WINDOW
E3 SILL

BASE DETAIL

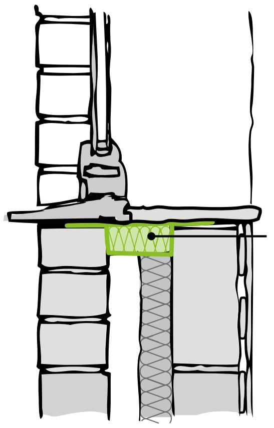
ψ 0.05



IMPROVED DETAIL

Use a cavity closer with a PU/PIR insulation core to improve the performance of sills and jambs.

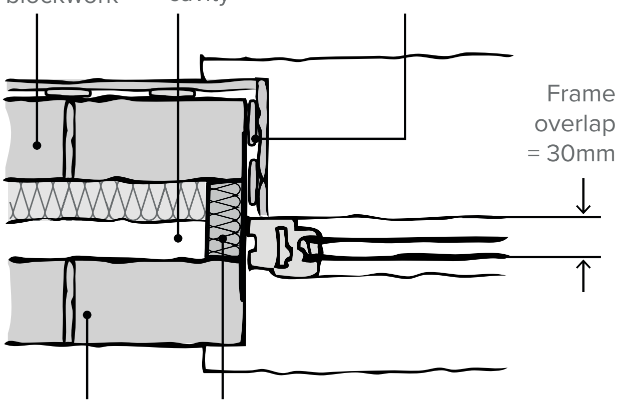
ψ 0.03



WINDOW
E4 JAMB

BASE DETAIL

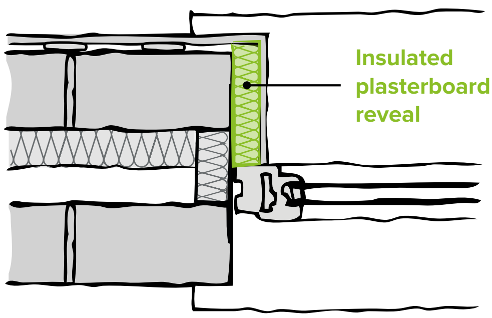
ψ 0.05



IMPROVED DETAIL

Use an insulated plasterboard reveal to improve the performance of window jambs.

ψ 0.03



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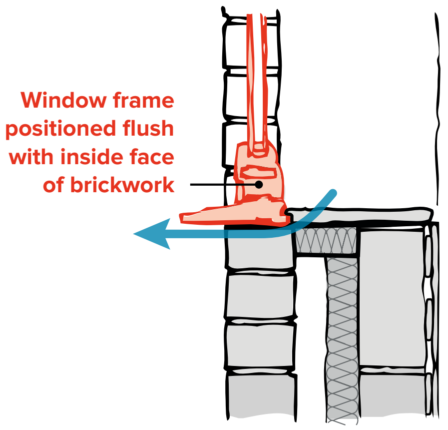
✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse for sills.

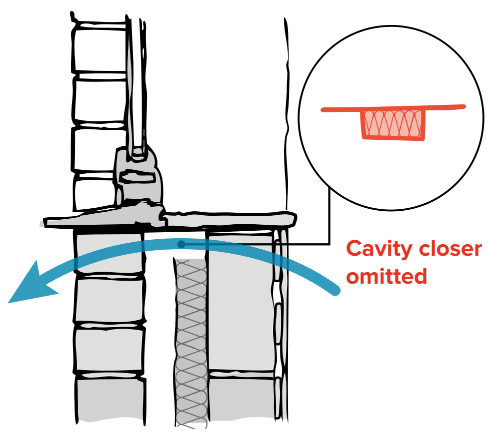
ψ 0.09



✖ PROBLEM TO AVOID

Omitting the cavity closer makes heat loss worse for sills.

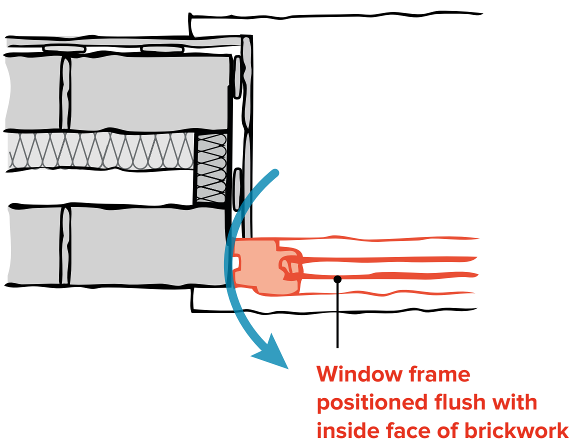
ψ 0.15



✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse for jambs.

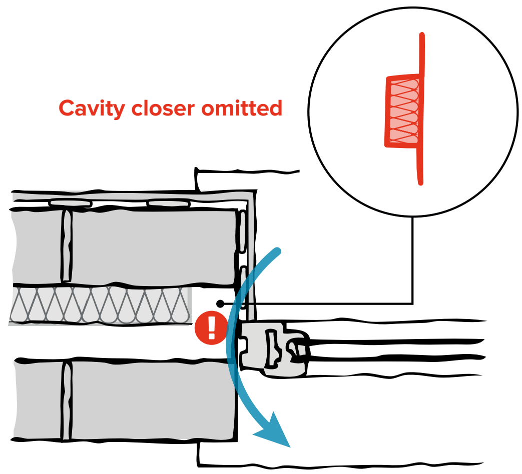
ψ 0.12



✖ PROBLEM TO AVOID

Omitting the cavity closer makes heat loss worse for jambs.

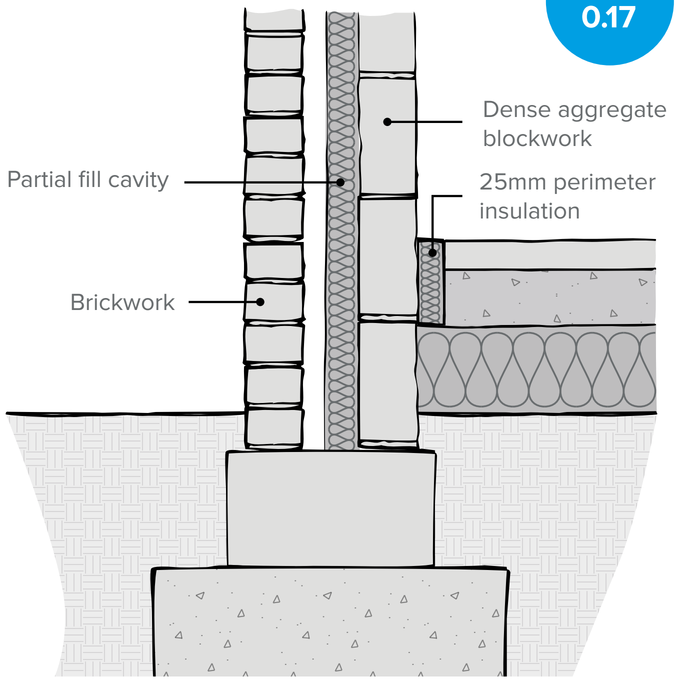
ψ 0.12



GROUND BEARING FLOOR
E5 EXTERNAL WALL

BASE DETAIL

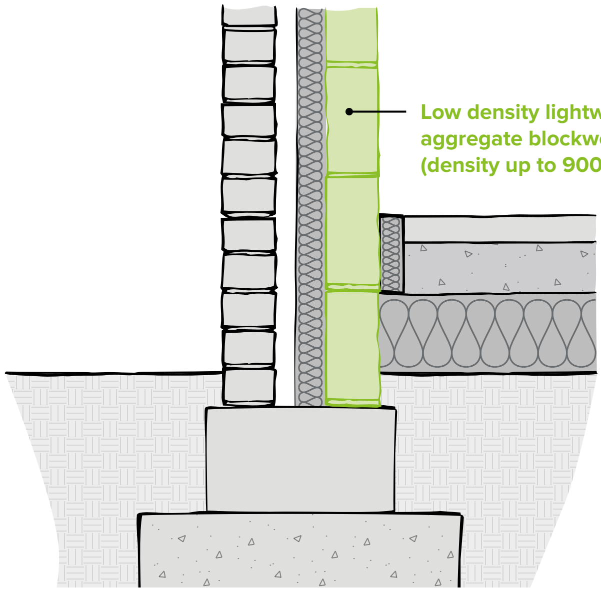
ψ 0.17



IMPROVED DETAIL

Use lightweight aggregate blockwork on the inner leaf to improve ground floor performance.

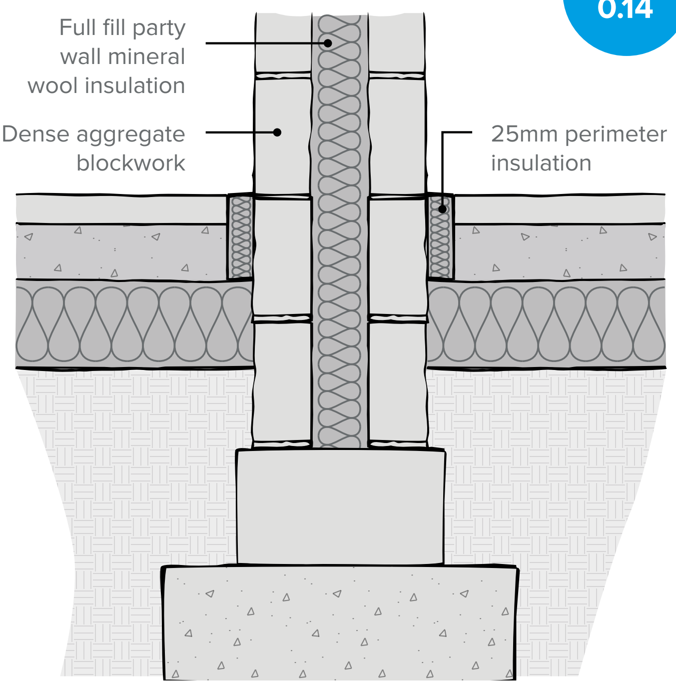
ψ 0.06



GROUND BEARING FLOOR
P1 PARTY WALL

BASE DETAIL

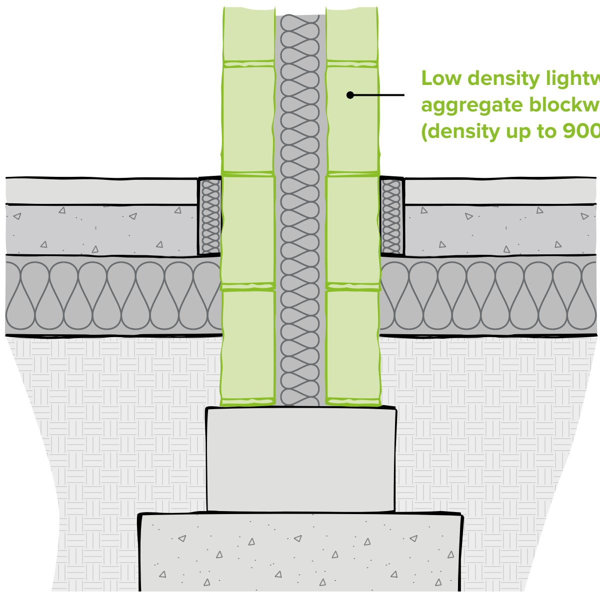
ψ 0.14



IMPROVED DETAIL

Use lightweight aggregate blockwork on the inner leaf to improve ground floor performance.

ψ 0.06

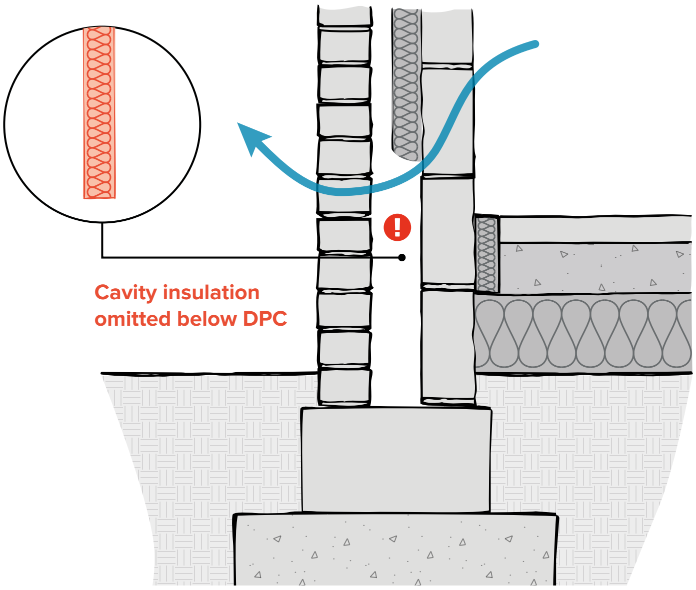


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

✖ PROBLEM TO AVOID

Omitting cavity insulation below DPC makes heat loss significantly worse.

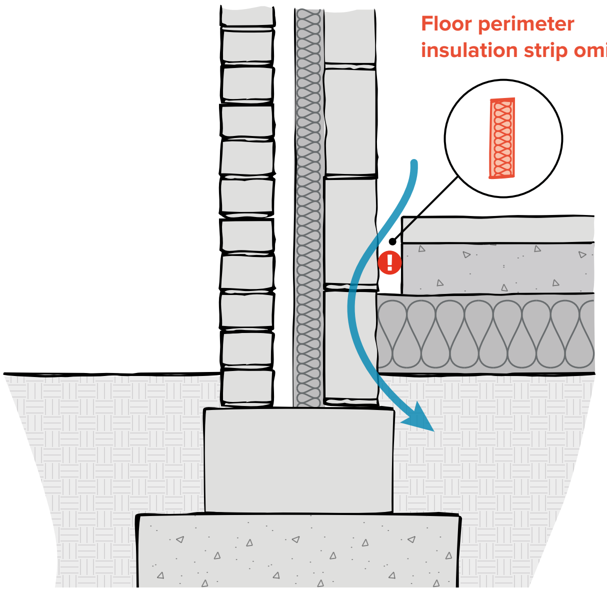
ψ 0.32



✖ PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss worse.

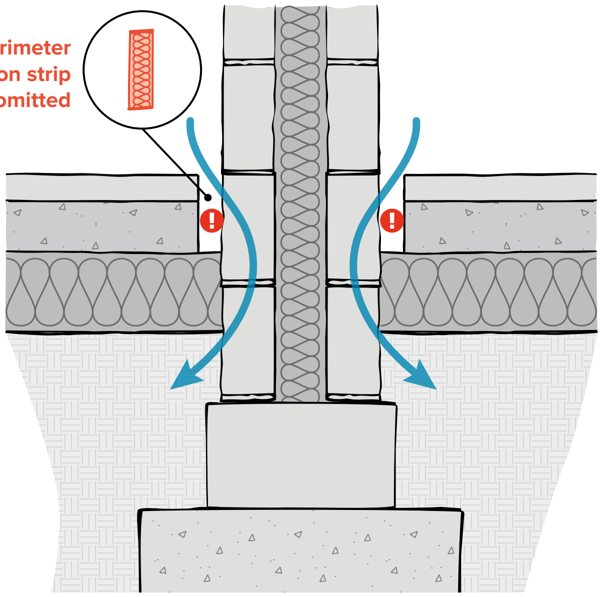
ψ 0.23



✖ PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss worse.

ψ 0.17



FURTHER NOTES

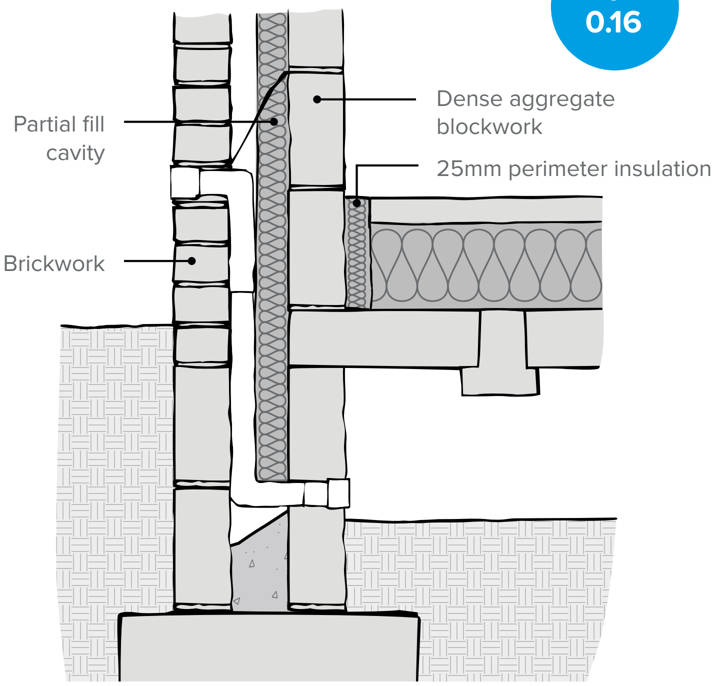
✖ CAVITY INSULATION OMISSION

Omitting the cavity insulation at the party wall base also makes heat loss worse.

BEAM AND BLOCK FLOOR
E5 EXTERNAL WALL

BASE DETAIL

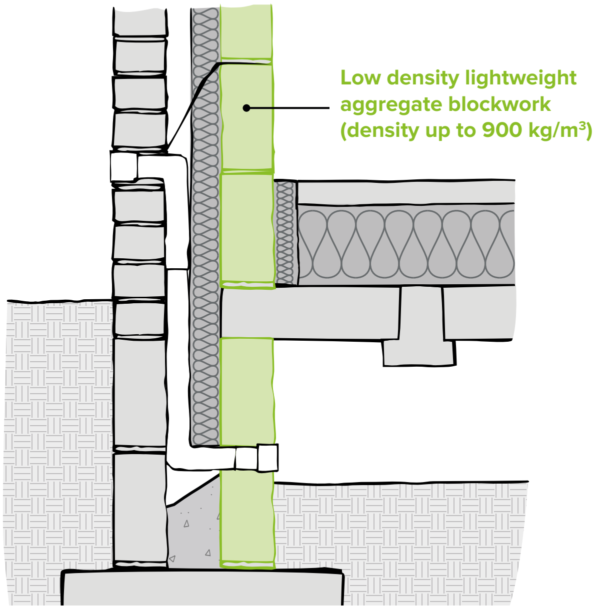
ψ 0.16



IMPROVED DETAIL

Use lightweight aggregate blockwork on the inner leaf to improve ground floor performance.

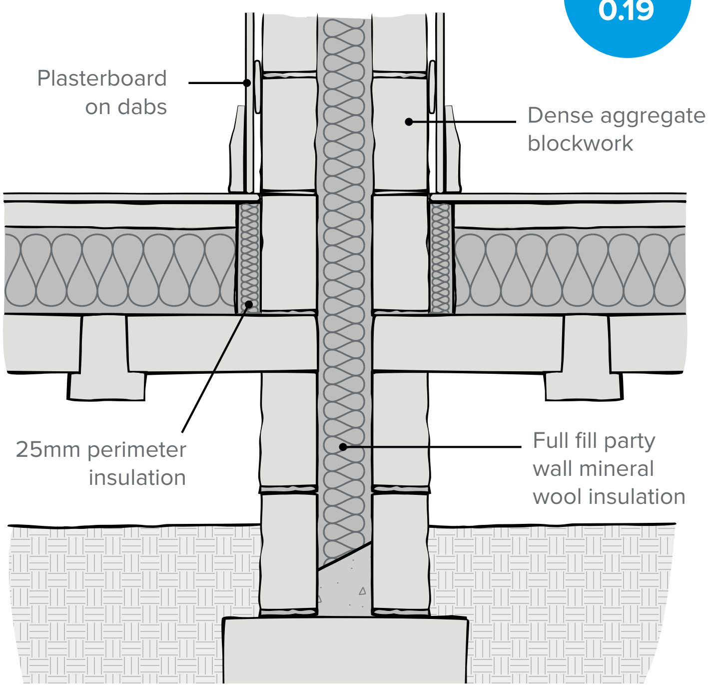
ψ 0.05



BEAM AND BLOCK FLOOR
P1 PARTY WALL

BASE DETAIL

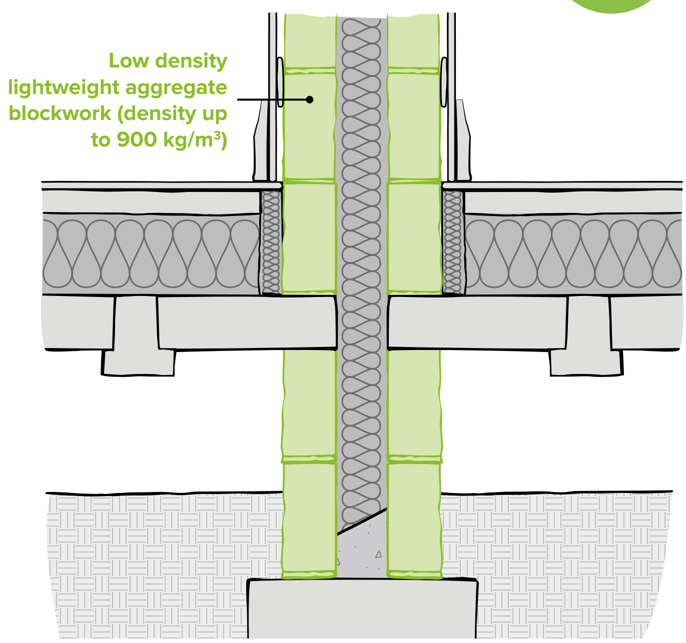
ψ 0.19



IMPROVED DETAIL

Use lightweight aggregate blockwork to improve ground floor performance.

ψ 0.06



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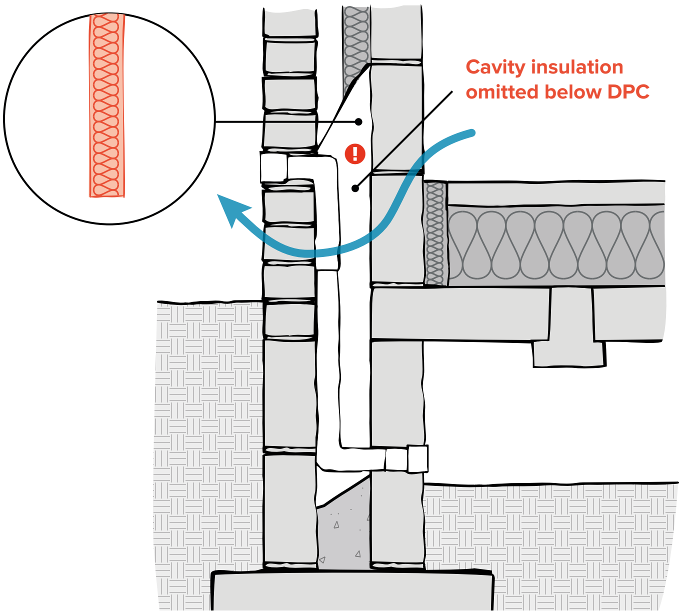
PROBLEM TO AVOID

Omitting cavity insulation below DPC makes heat loss significantly worse.

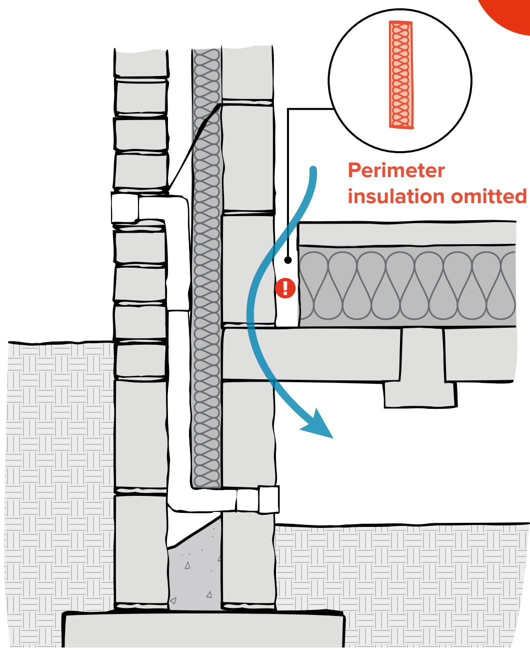
ψ 0.26



PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss worse.

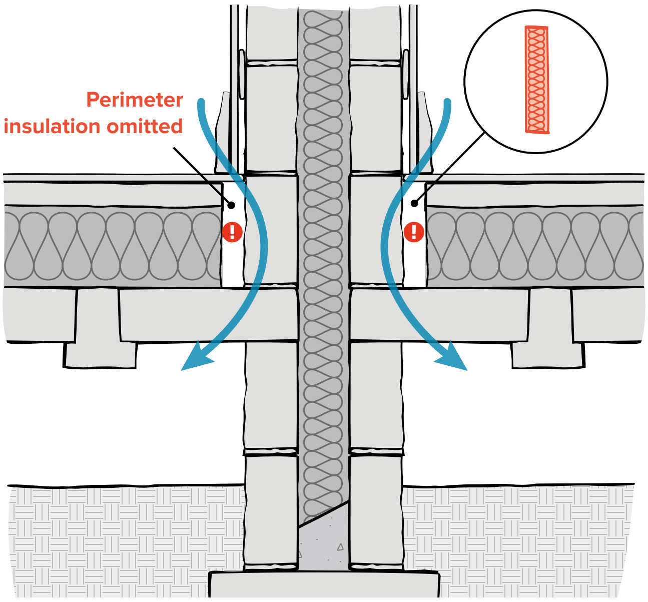
ψ 0.19



PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss worse.

ψ 0.21



FURTHER NOTES

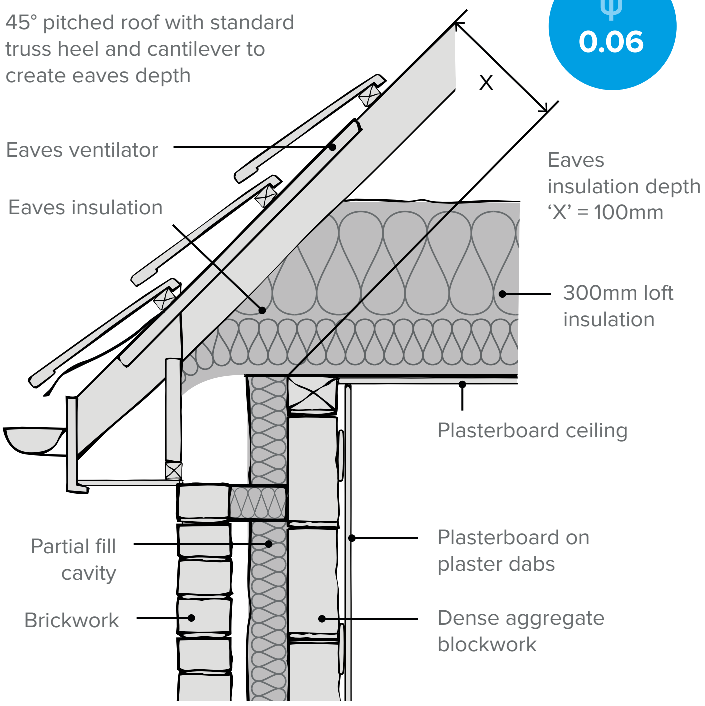
CAVITY INSULATION OMISSION

Omitting the cavity insulation at the party wall base also makes heat loss worse.

COLD ROOF
E10 EAVES

BASE DETAIL

ψ 0.06

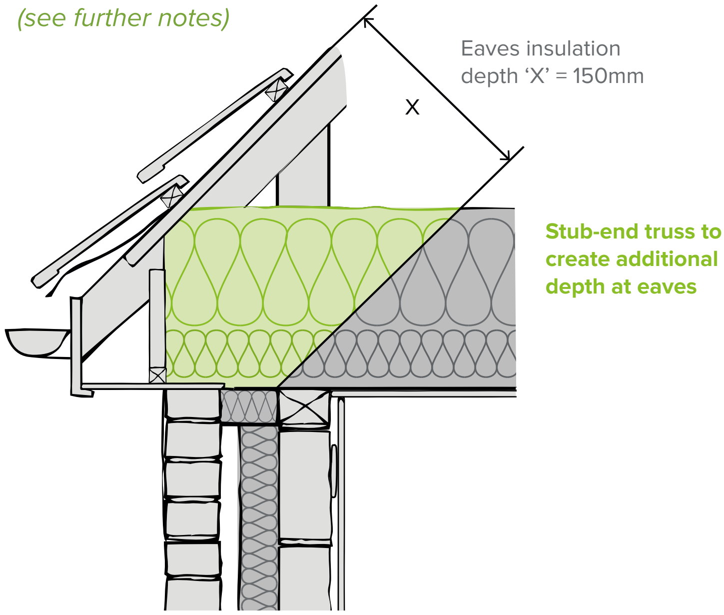


IMPROVED DETAIL

Increase the eaves insulation depth 'X' to improve eaves performance.

Note – this may influence the truss design (see further notes)

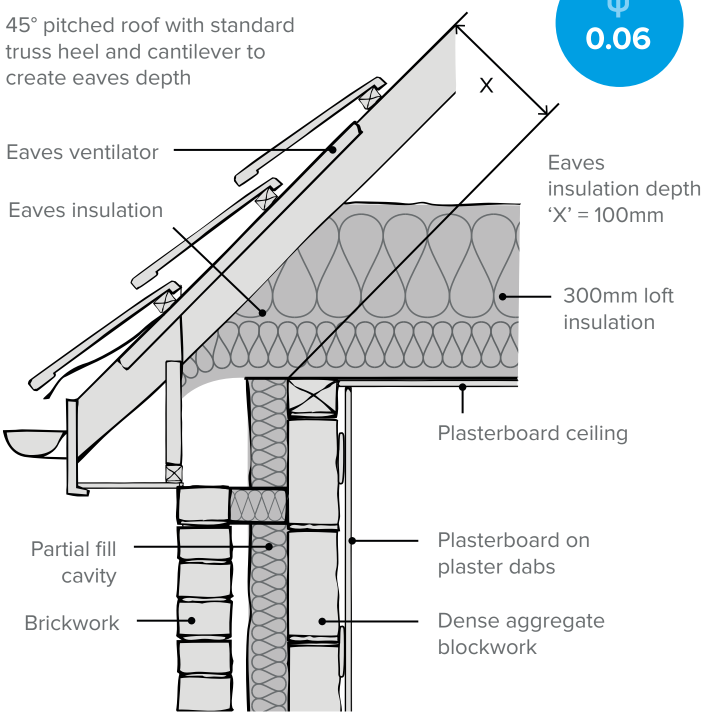
ψ 0.04



COLD ROOF
E10 EAVES

BASE DETAIL

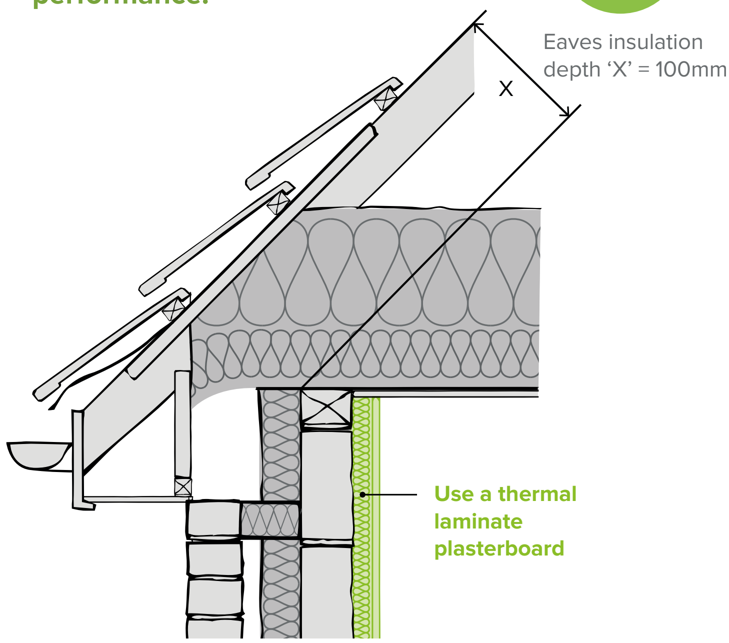
ψ 0.06



IMPROVED DETAIL

Use insulated plasterboard on inner blockwork leaf to improve eaves performance.

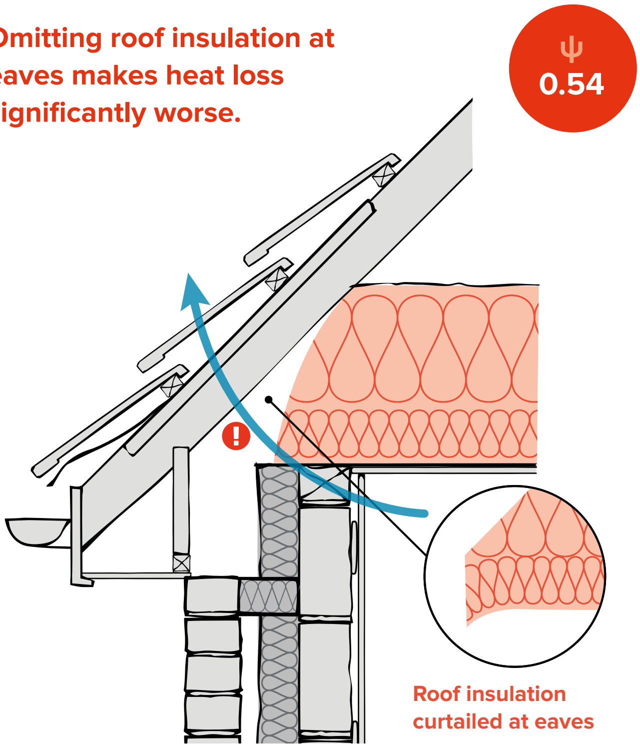
ψ 0.04



NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

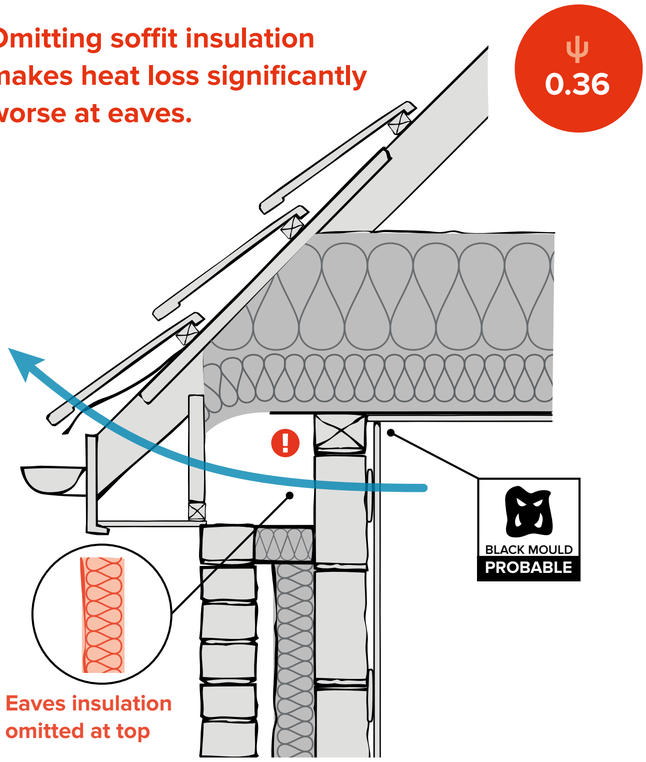
PROBLEM TO AVOID

Omitting roof insulation at eaves makes heat loss significantly worse.



PROBLEM TO AVOID

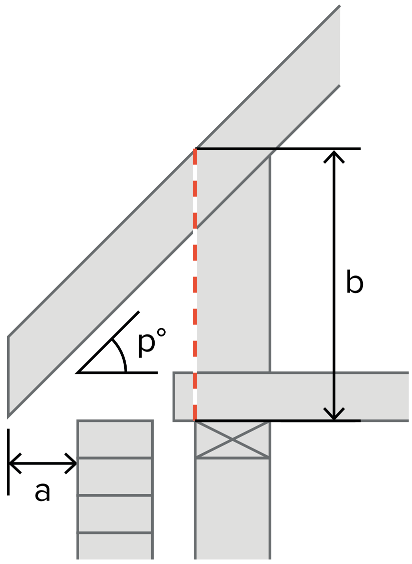
Omitting soffit insulation makes heat loss significantly worse at eaves.

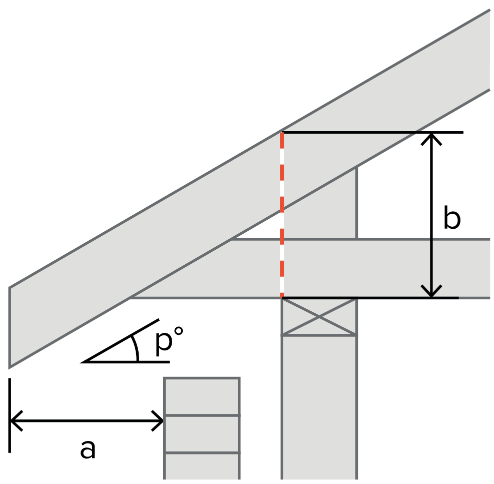


FURTHER NOTES

ADVISE TRUSS DESIGNERS OF INSULATION SPACE REQUIREMENTS

Specifying the desired roof pitch (p°), eaves overhang (a) and eaves insulation depth (b) will enable truss designers to select the most appropriate truss heel detail to meet these requirements.

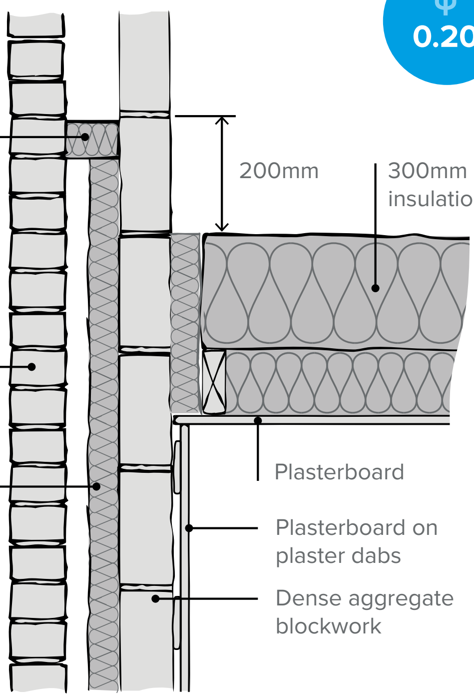




COLD ROOF
E12 GABLE

BASE DETAIL

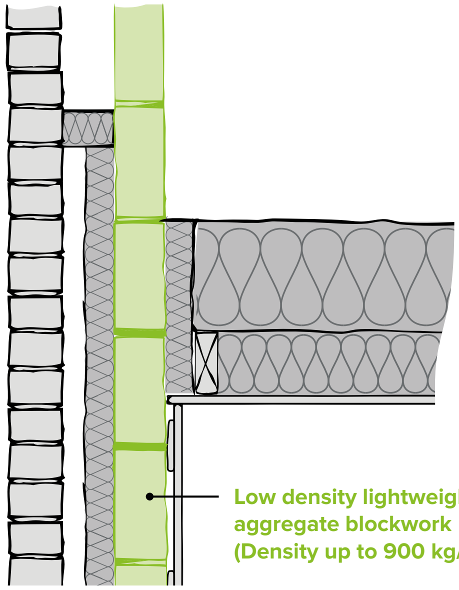
ψ 0.20



IMPROVED DETAIL

Use lightweight aggregate blockwork on the inner leaf to improve gable performance.

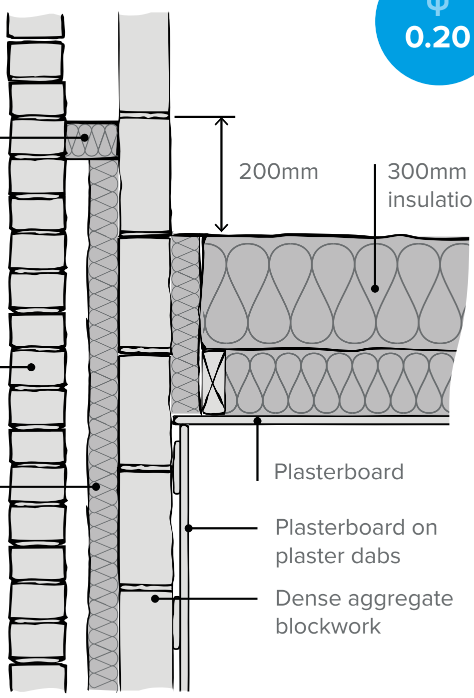
ψ 0.08



COLD ROOF
E12 GABLE

BASE DETAIL

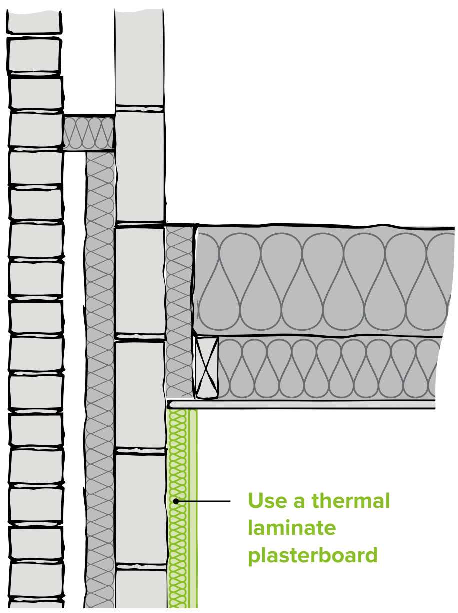
ψ 0.20



IMPROVED DETAIL

Use insulated plasterboard on inner blockwork leaf to improve gable performance.

ψ 0.12

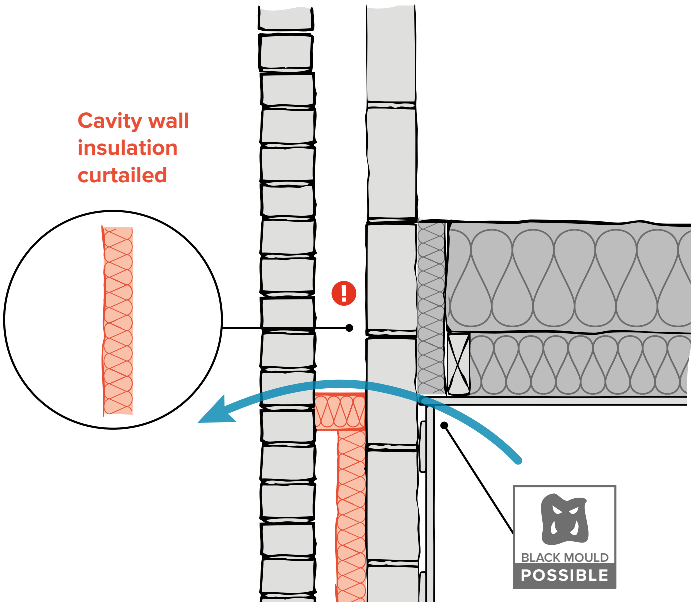


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

PROBLEM TO AVOID

Stopping the cavity wall insulation short makes heat loss significantly worse at gables.

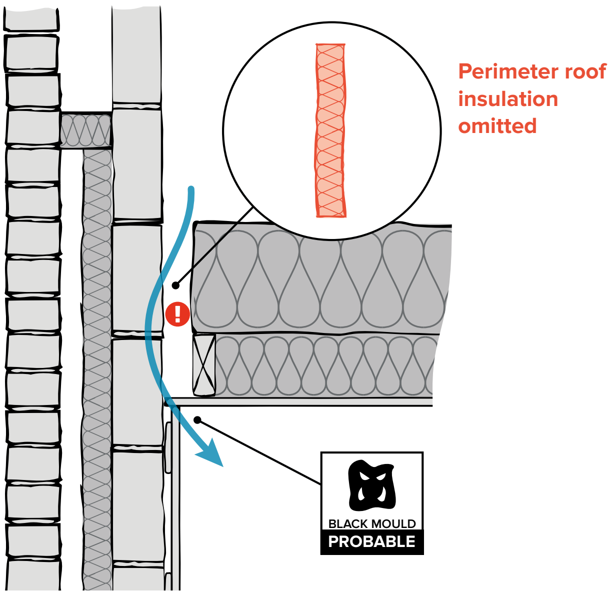
ψ 0.39



PROBLEM TO AVOID

Omitting the roof perimeter insulation makes heat loss significantly worse at gables.

ψ 0.58

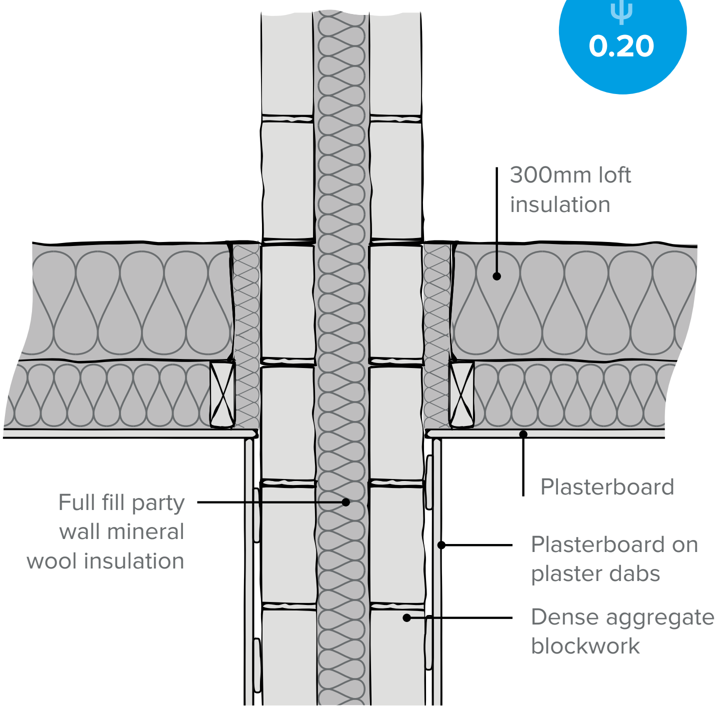


FURTHER NOTES

COLD ROOF
P4 PARTY WALL HEAD

BASE DETAIL

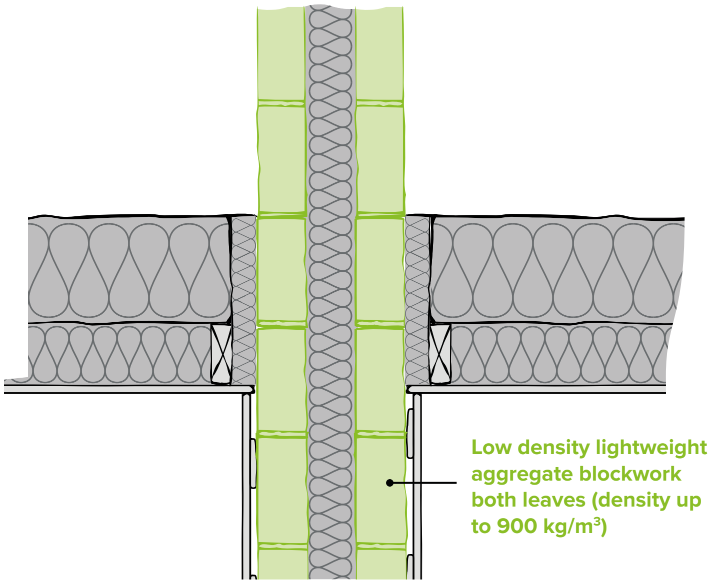
ψ 0.20



IMPROVED DETAIL

Use lightweight aggregate blockwork for the party wall leaves to improve thermal performance.

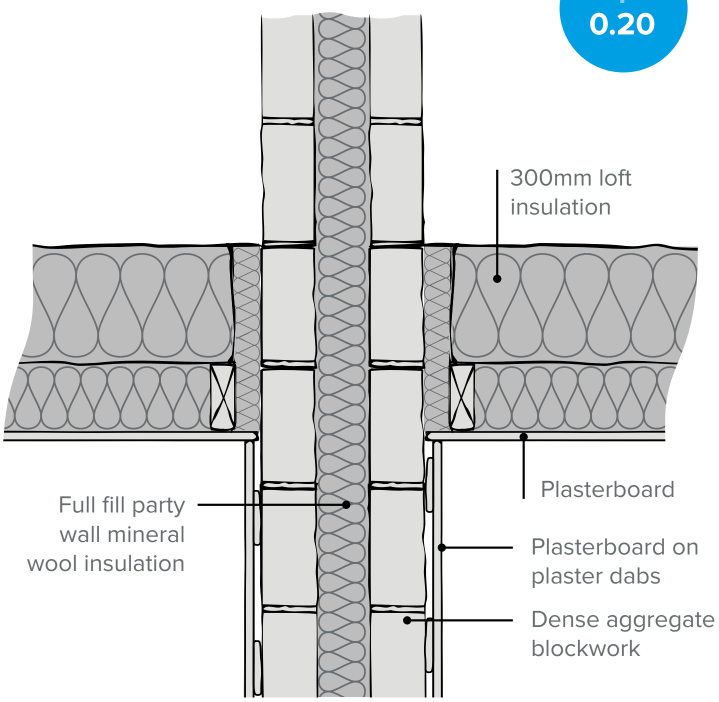
ψ 0.06



COLD ROOF
P4 PARTY WALL HEAD

BASE DETAIL

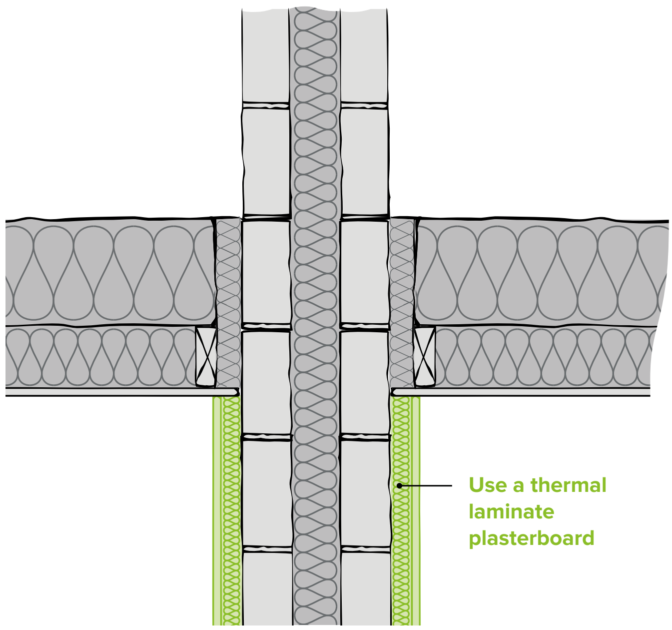
ψ 0.20



IMPROVED DETAIL

Use insulated plasterboard on party wall leaves to improve thermal performance.

ψ 0.16

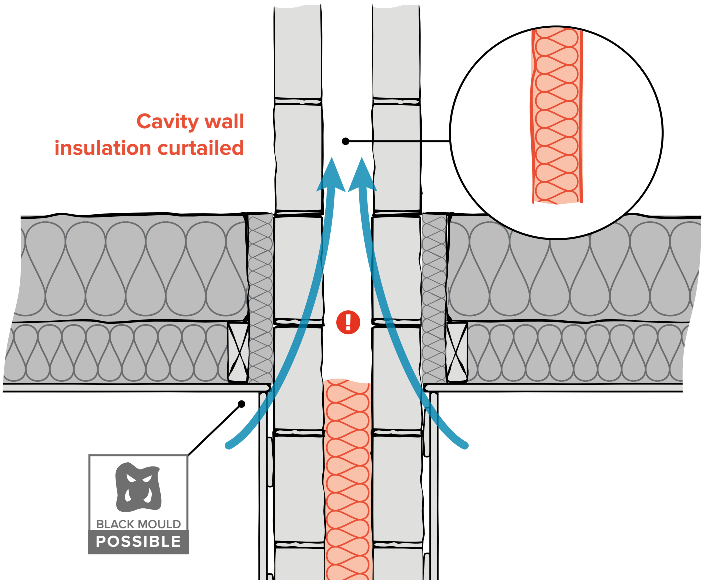


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

PROBLEM TO AVOID

Stopping the wall cavity insulation short makes heat loss significantly worse at party walls.

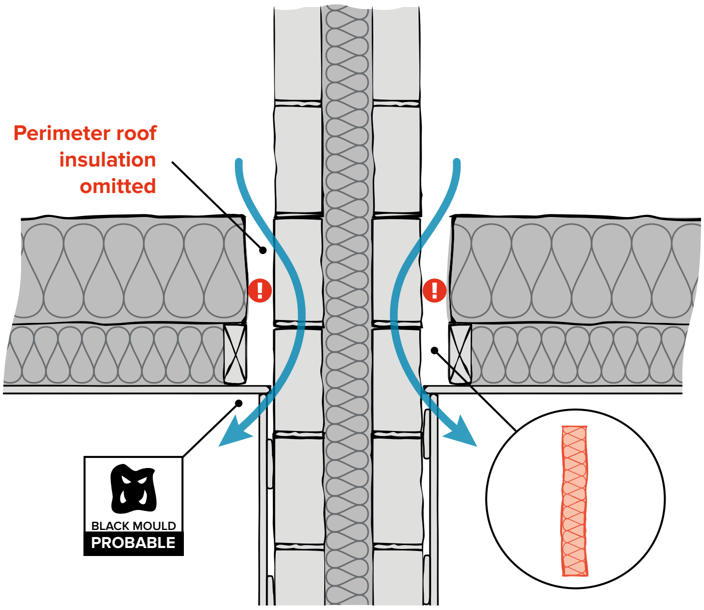
ψ 0.40



PROBLEM TO AVOID

Omitting the roof perimeter insulation between truss and wall makes heat loss significantly worse at party walls.

ψ 0.59



FURTHER NOTES

TIMBER FRAME CONSTRUCTION

KEY DESIGN RECOMMENDATIONS

	Design recommendation	No. of junctions affected	Junction references
1	Use thermal laminate plasterboard on inside of frame	5	E2, E4, E5, E6, E10 (pages 24, 26, 28, 30, 32, 34)
2	Use beam and block ground floor instead of ground bearing slab	1	E5 (pages 28, 30)
3	Use light aggregate footing blocks	2	E5, P1 (pages 28, 30)
4	Use min. 50mm floor perimeter insulation thickness	2	E5, P1 (pages 28, 30)
5	Use a window frame overlap of min. 50mm	3	E2, E3, E4 (pages 24, 26)
6	Use min. 150mm insulation behind rimboard	1	E6 (page 32)
7	Use a PU/PIR cavity closer	2	E3, E4 (pages 26)
8	Increase eaves insulation depth	1	E10 (page 34)
9	Use PU/PIR cavity lintel insulation	1	E2 (page 24)

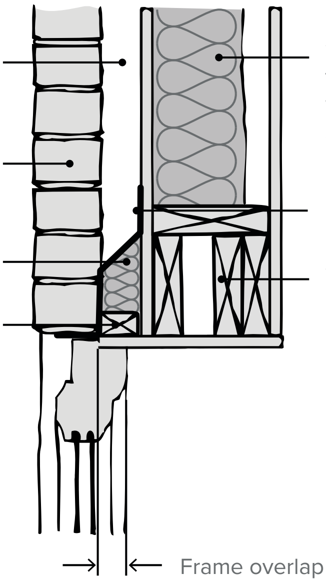
KEY PROBLEMS TO AVOID

	Problem / site check	No. of junctions affected	Junction references	Black mould risk
1	Omitting ground floor perimeter insulation	2	E5, P1 (pages 28, 30)	
2	Omitting rafter insulation at eaves	1	E10 (page 34)	BLACK MOULD PROBABLE
3	Omitting rimboard insulation	1	E6 (page 32)	BLACK MOULD POSSIBLE
4	No window frame overlap with cavity	3	E2, E3, E4 (pages 24, 26)	
5	Omitting the cavity closure	2	E3, E4 (page 26)	BLACK MOULD PROBABLE
6	Omitting soffit insulation at eaves	1	E10 (page 34)	BLACK MOULD PROBABLE
7	No cavity lintel insulation	1	E2 (page 24)	

LINTELS
E2 TIMBER FRAME LINTEL

BASE DETAIL

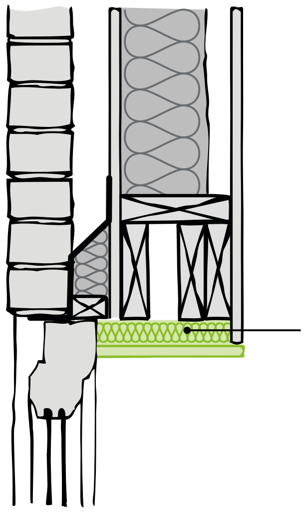
ψ 0.15



IMPROVED DETAIL

Use an insulated plasterboard reveal to improve performance of timber frame lintels.

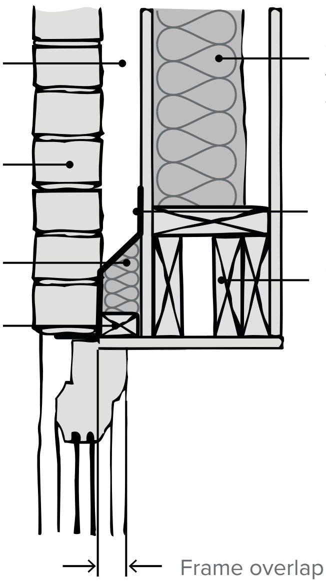
ψ 0.10



LINTELS
E2 TIMBER FRAME LINTEL

BASE DETAIL

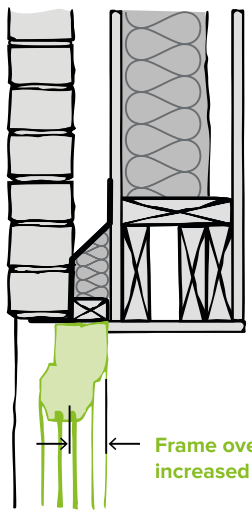
ψ 0.15



IMPROVED DETAIL

Increase the window frame overlap to improve performance of timber frame lintels.

ψ 0.13

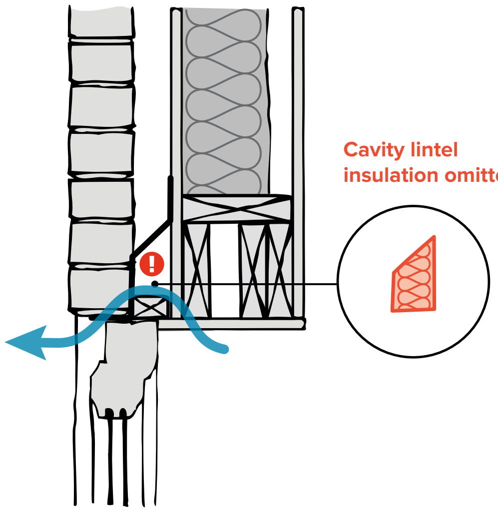


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

✖ PROBLEM TO AVOID

Omitting the cavity lintel insulation makes heat loss worse.

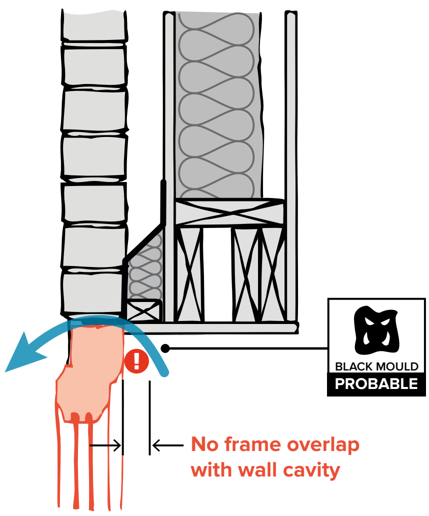
ψ 0.18



✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse.

ψ 0.22



FURTHER NOTES

✔ CAVITY LINTEL INSULATION

Upgrading the cavity lintel insulation to PU/PIR will reduce heat loss.

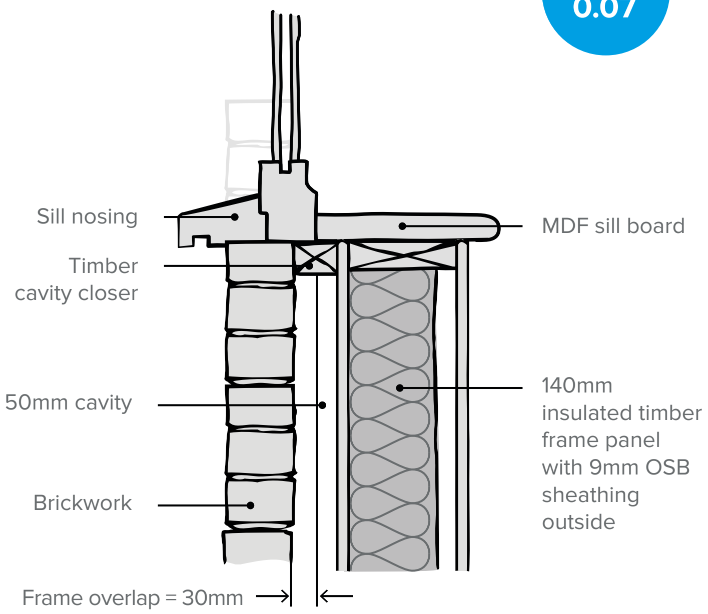
✔ THERMAL LAMINATE PLASTERBOARD

Using a thermal laminate plasterboard on the external timber frame wall will reduce heat loss.

WINDOW
E3 SILL

BASE DETAIL

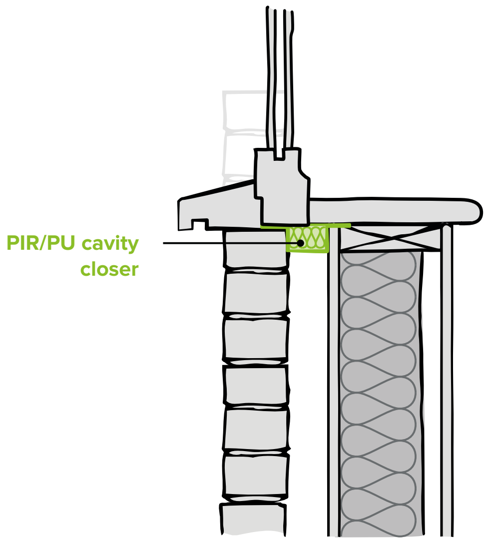
ψ 0.07



IMPROVED DETAIL

Use a cavity closer with a PU/PIR insulation core to improve performance of sills and jambs.

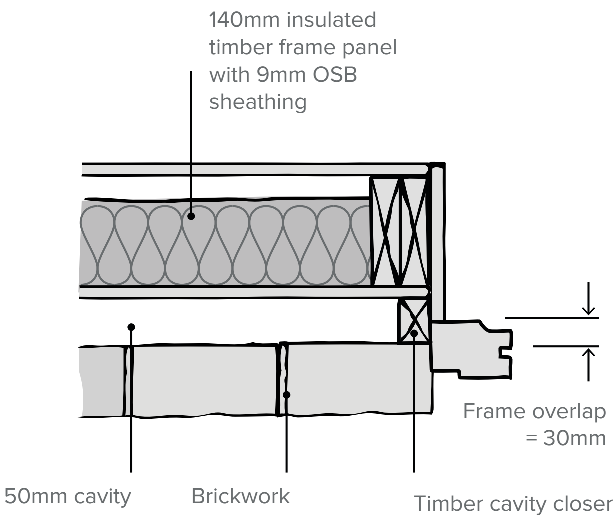
ψ 0.06



WINDOW
E4 JAMB

BASE DETAIL

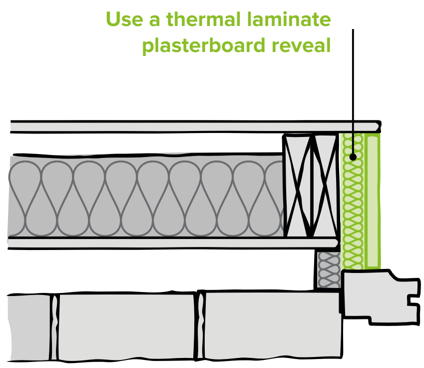
ψ 0.10



IMPROVED DETAIL

Use an insulated plasterboard reveal to improve the performance of window jambs.

ψ 0.06

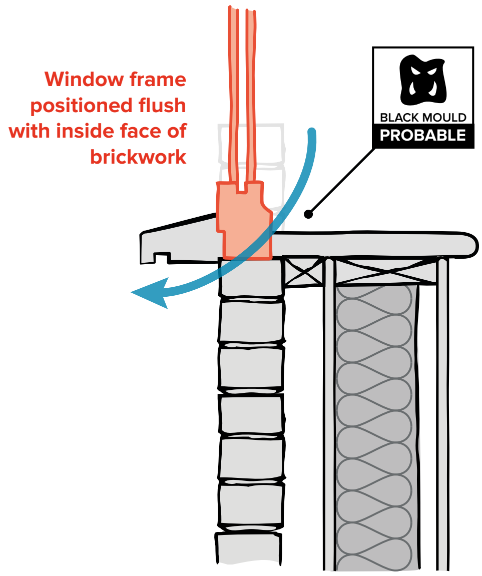


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse for sills.

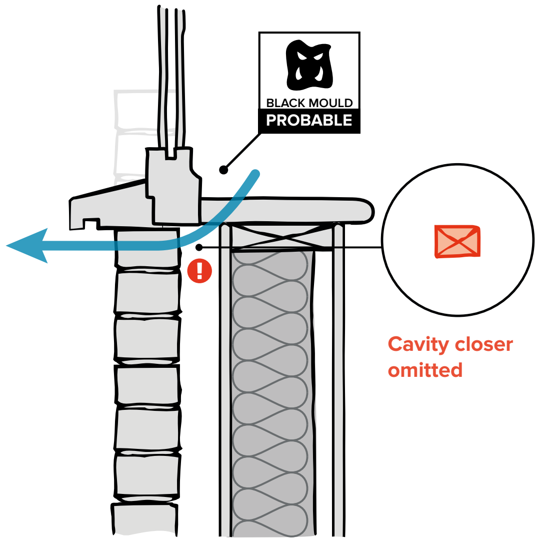
ψ 0.11



✖ PROBLEM TO AVOID

Omitting the cavity closer makes heat loss worse for sills.

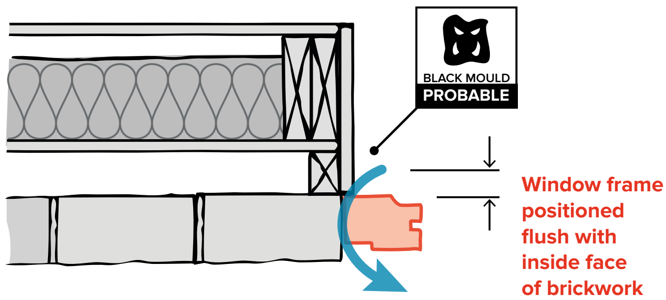
ψ 0.09



✖ PROBLEM TO AVOID

Reducing the frame overlap to 0mm makes heat loss worse for jambs.

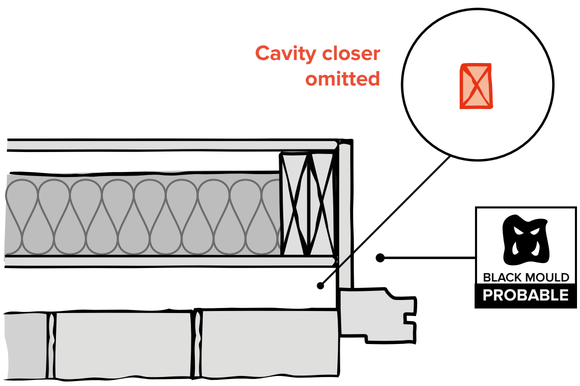
ψ 0.15



✖ PROBLEM TO AVOID

Omitting the cavity closer makes heat loss worse for jambs.

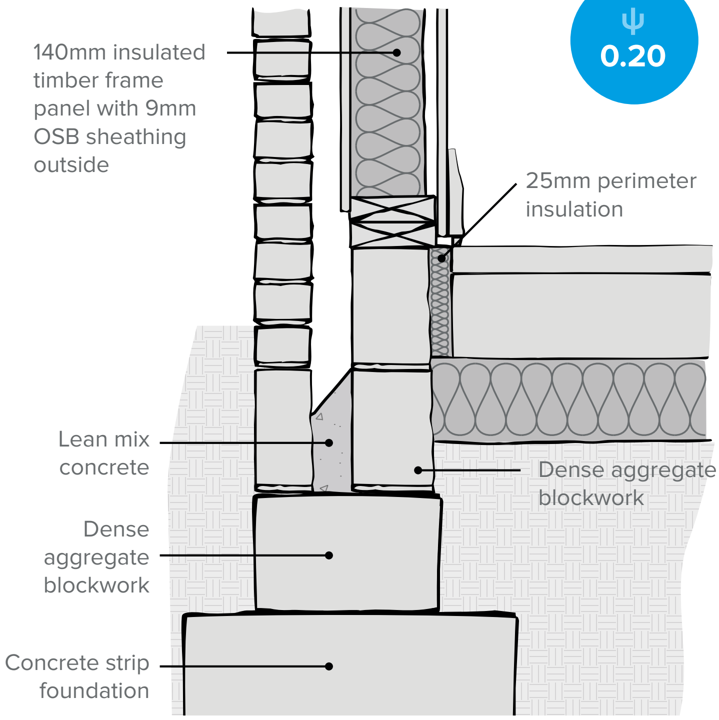
ψ 0.13



GROUND BEARING FLOOR
E5 EXTERNAL WALL

BASE DETAIL

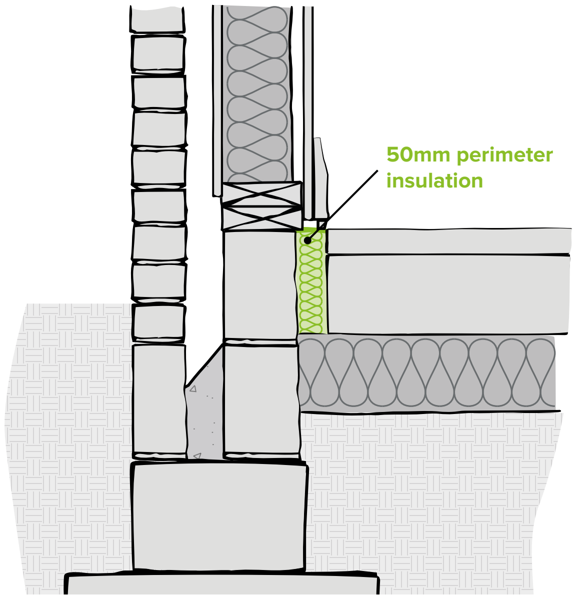
ψ 0.20



IMPROVED DETAIL

Increase the perimeter insulation thickness to improve ground floor performance.

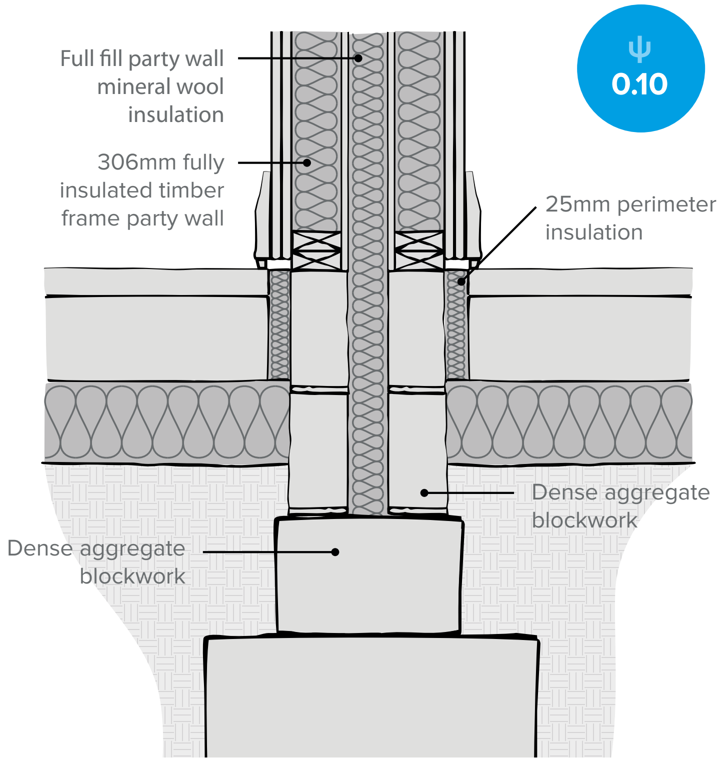
ψ 0.16



GROUND BEARING FLOOR
P1 PARTY WALL

BASE DETAIL

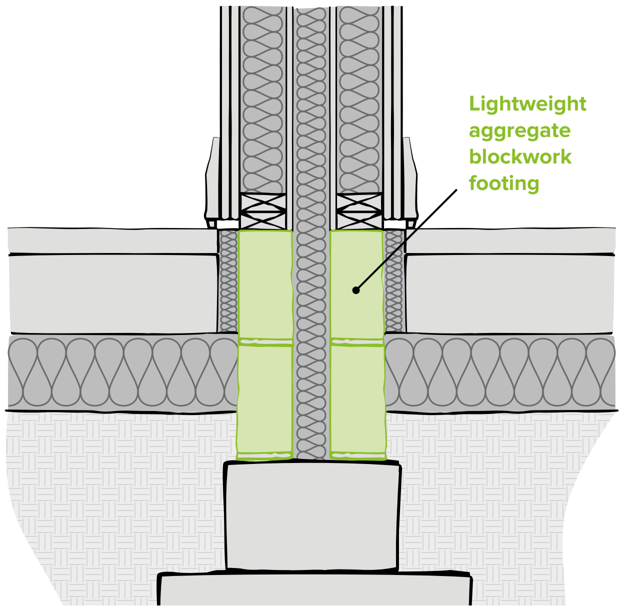
ψ 0.10



IMPROVED DETAIL

Use lightweight aggregate footing blockwork to improve ground floor performance.

ψ 0.05

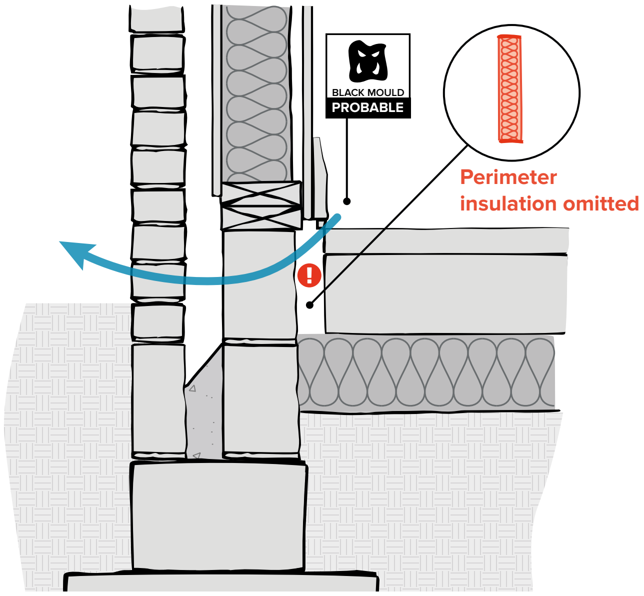


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss significantly worse.

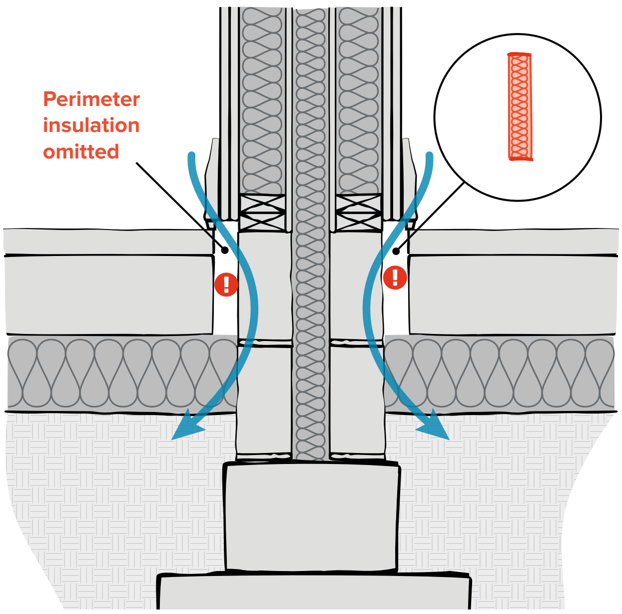
ψ 0.50



PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss worse.

ψ 0.16



FURTHER NOTES

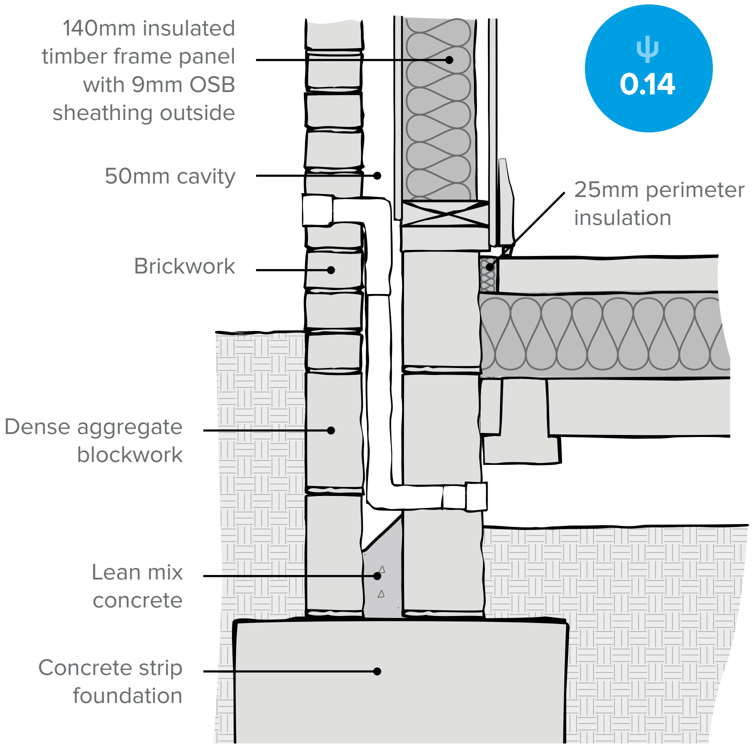
THERMAL LAMINATE PLASTERBOARD

Using a thermal laminate plasterboard on the timber frame wall will reduce heat loss.

BEAM AND BLOCK FLOOR
E5 EXTERNAL WALL

BASE DETAIL

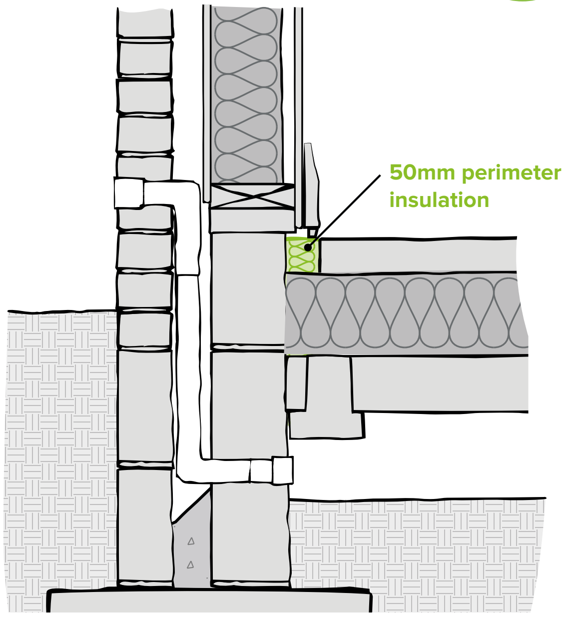
ψ 0.14



IMPROVED DETAIL

Increase the perimeter insulation thickness to improve ground floor performance.

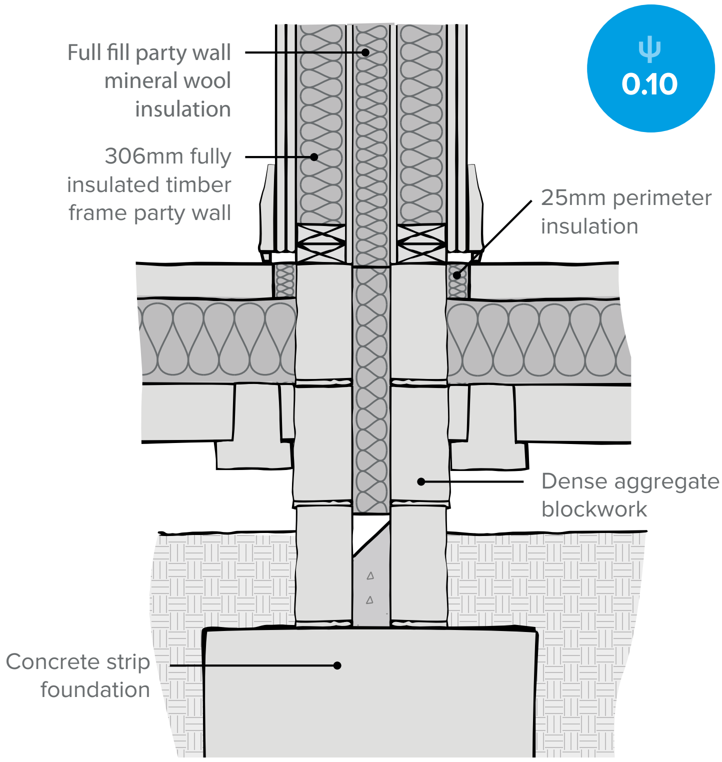
ψ 0.11



BEAM AND BLOCK FLOOR
P1 PARTY WALL

BASE DETAIL

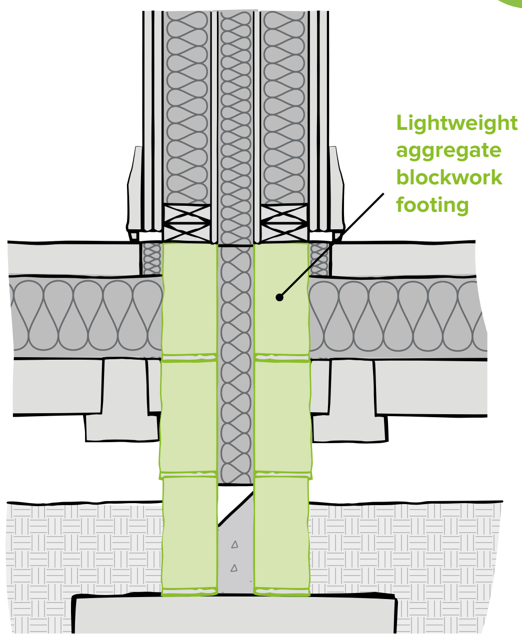
ψ 0.10



IMPROVED DETAIL

Use lightweight aggregate footing blockwork to improve ground floor performance.

ψ 0.05

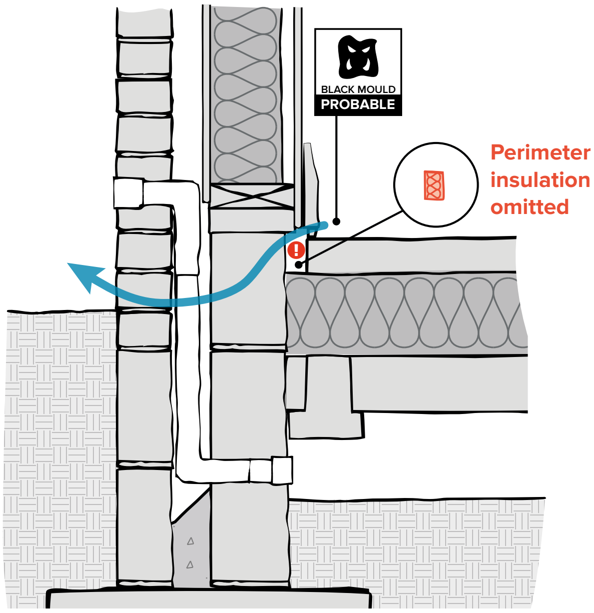


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss significantly worse.

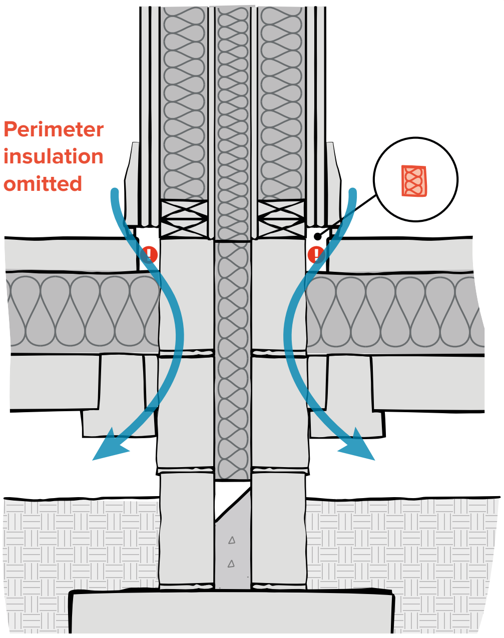
ψ 0.30



PROBLEM TO AVOID

Omitting the floor perimeter insulation makes heat loss worse.

ψ 0.18



FURTHER NOTES

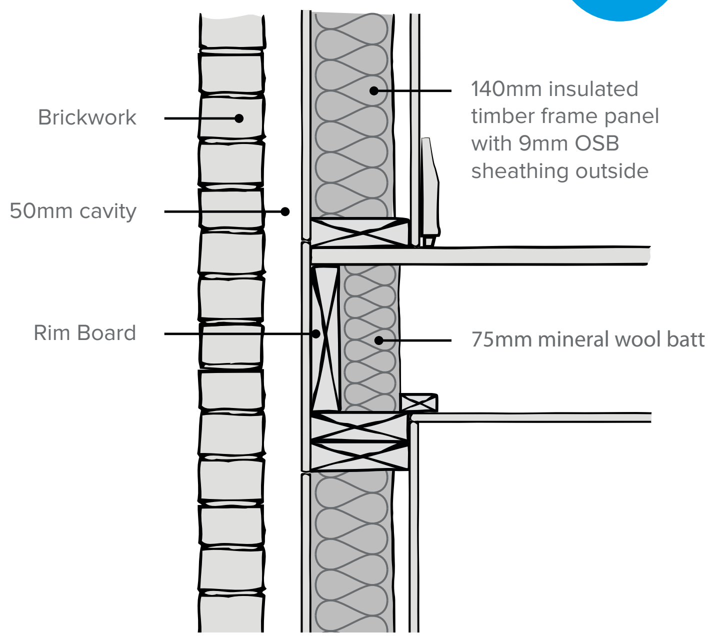
THERMAL LAMINATE PLASTERBOARD

Using a thermal laminate plasterboard on the timber frame wall will reduce heat loss.

TIMBER FLOOR
E6 INTERMEDIATE FLOOR

BASE DETAIL

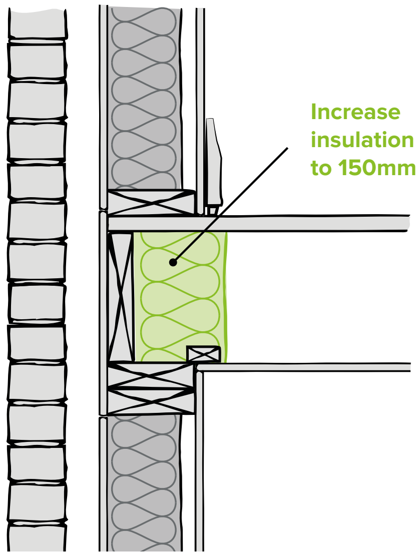
ψ 0.11



IMPROVED DETAIL

Increase the rimboard insulation thickness to improve intermediate floor performance.

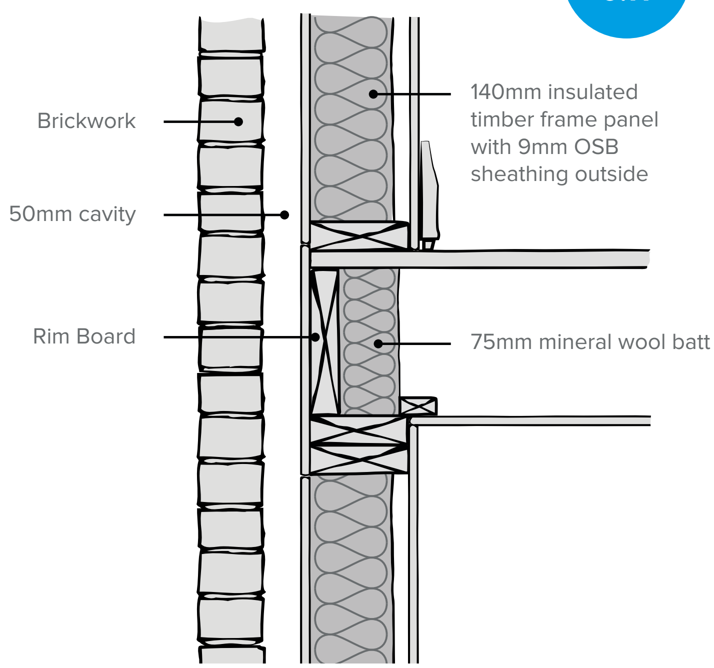
ψ 0.08



TIMBER FLOOR
E6 INTERMEDIATE FLOOR

BASE DETAIL

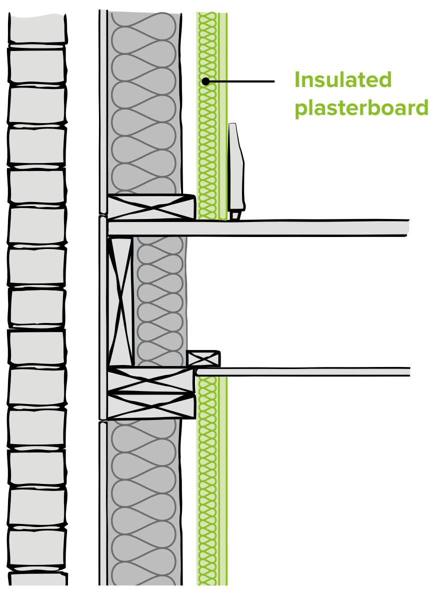
ψ 0.11



IMPROVED DETAIL

Use an insulated plasterboard on the inside of the frame to improve intermediate floor performance.

ψ 0.09

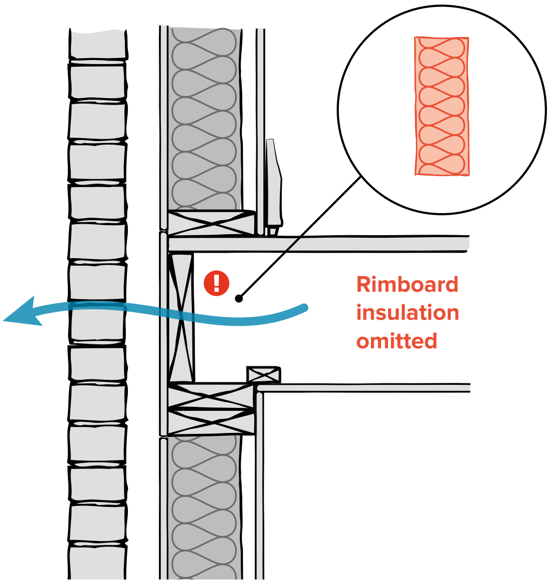


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

PROBLEM TO AVOID

Omitting the rimboard insulation makes heat loss significantly worse at intermediate floors.

ψ 0.26

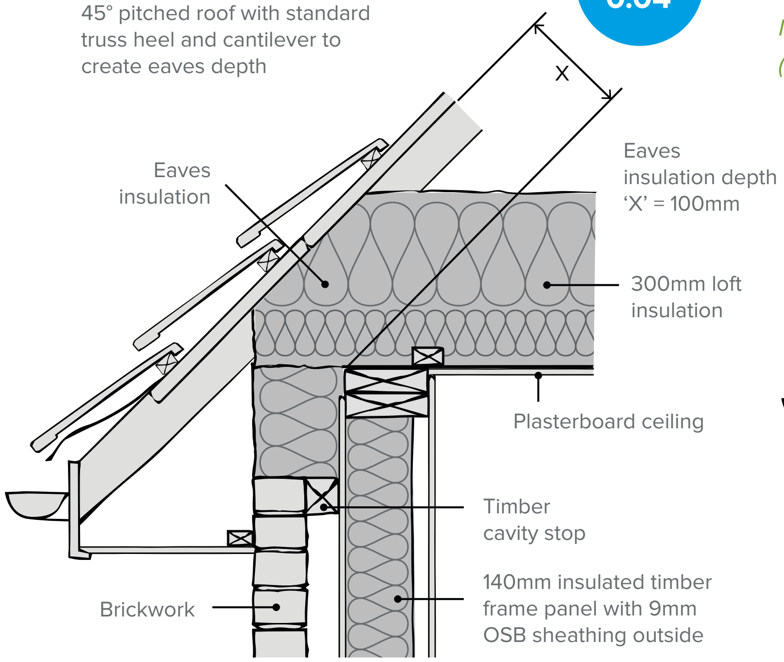


FURTHER NOTES

COLD ROOF
E10 EAVES

BASE DETAIL

ψ 0.04

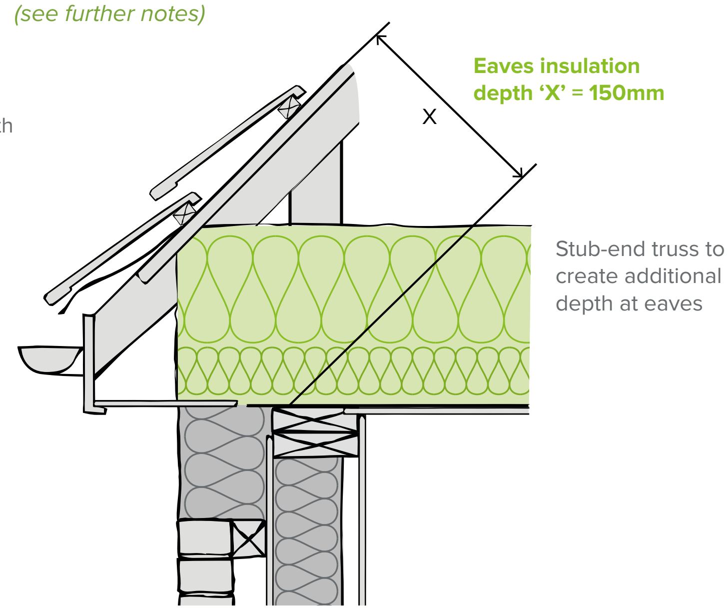


IMPROVED DETAIL

Increase the eaves insulation depth 'X' to improve performance.

Note – this may influence the truss design (see further notes)

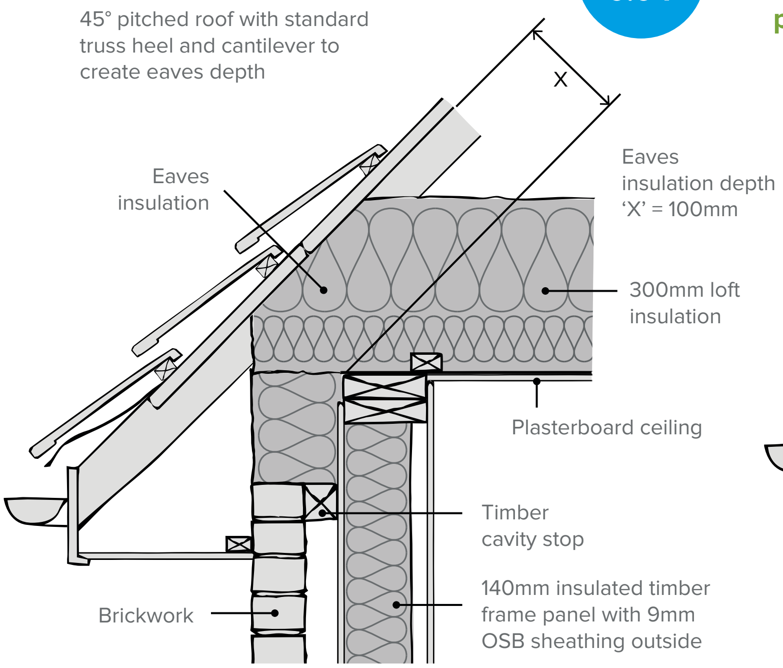
ψ 0.03



COLD ROOF
E10 EAVES

BASE DETAIL

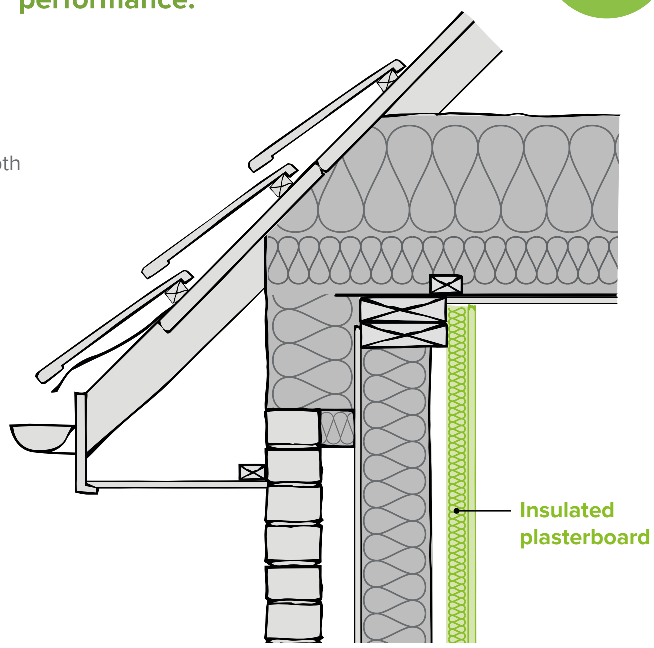
ψ 0.04



IMPROVED DETAIL

Use insulated plasterboard on the inside of the frame to improve eaves performance.

ψ 0.03

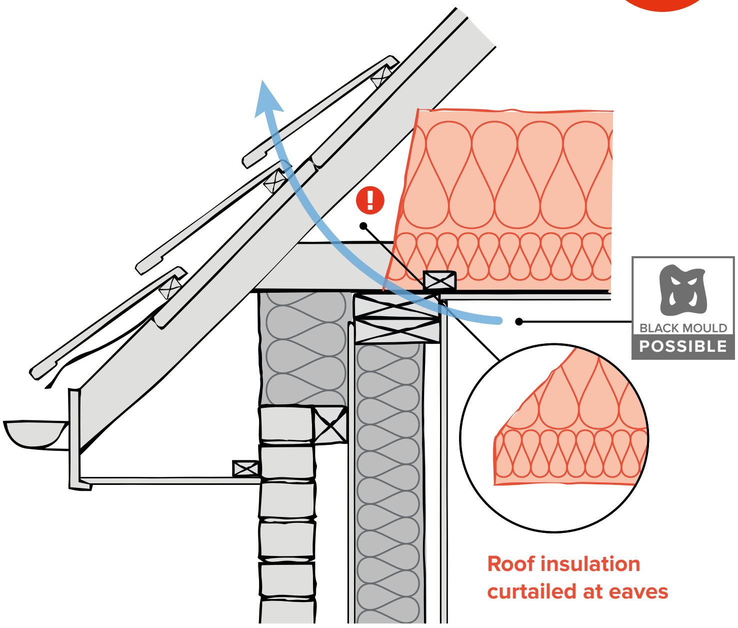


NB: The PSI-values quoted in this Guide are for indicative purposes only and should not be used in SAP calculations

PROBLEM TO AVOID

Omitting roof insulation at eaves makes heat loss significantly worse.

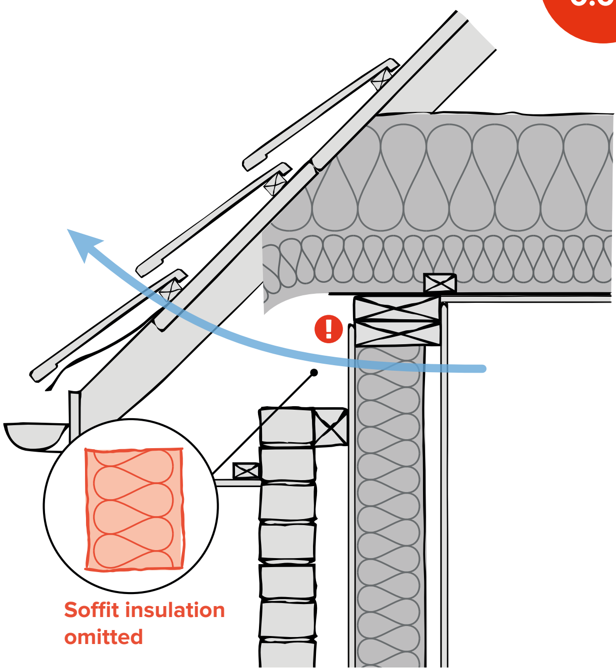
ψ 0.21



PROBLEM TO AVOID

Omitting soffit insulation makes heat loss worse at eaves.

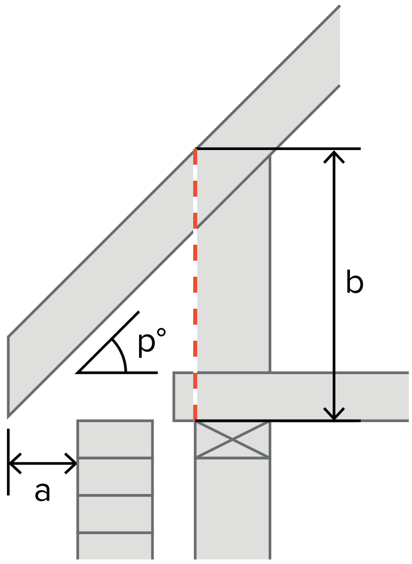
ψ 0.09

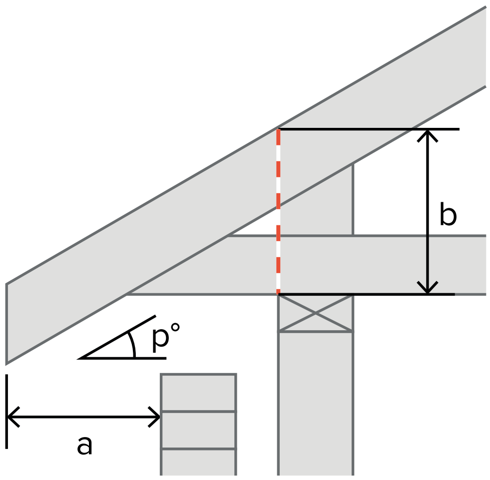


FURTHER NOTES

ADVISE TRUSS DESIGNERS OF INSULATION SPACE REQUIREMENTS

Specifying the desired roof pitch (p°), eaves overhang (a) and eaves insulation depth (b) will enable the truss designer to select the most appropriate truss heel detail to meet these requirements.





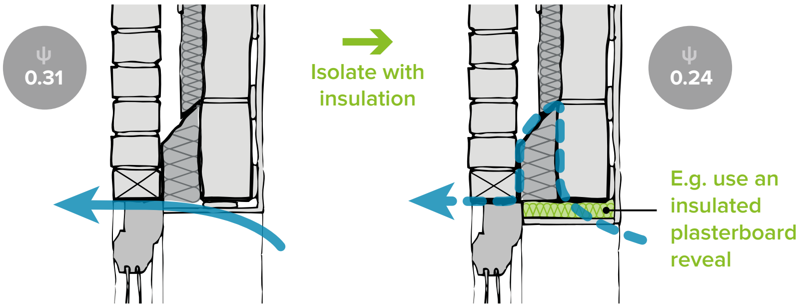
THERMAL BRIDGING GUIDE
ANNEX

HOW DO I IMPROVE JUNCTION PERFORMANCE?

Thermal bridging heat losses occur when the integrity of the insulation envelope of a building is compromised by a more conductive material. The diagrams below illustrate four alternative ways in which the effects of cold-bridges at building junctions can be reduced or negated using a masonry lintel as an example. In the main body of the Guide one or more of these strategies are used to show how each of the most important PSI-values in dwellings can be reduced and by how much.

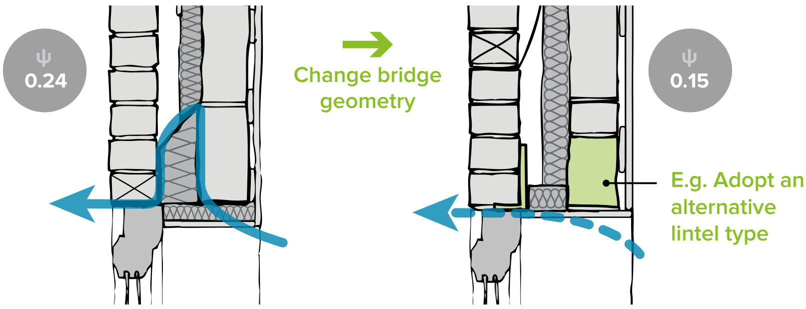
1. ISOLATE THE THERMAL BRIDGE WITH INSULATION

Use a layer of insulation to minimise direct contact of the thermal bridge with either the inside or outside temperature.



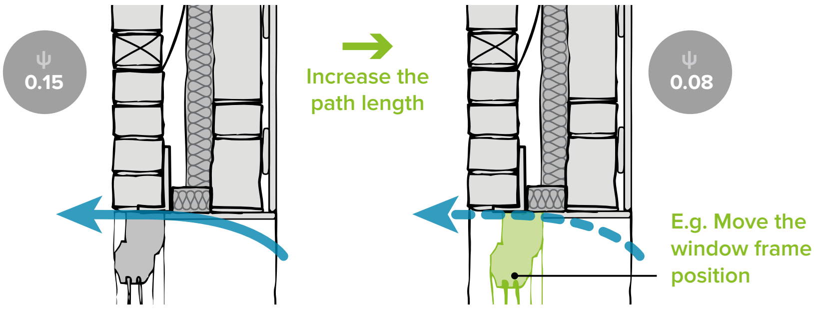
2. CHANGE THE THERMAL BRIDGE GEOMETRY

Move, remove or reduce the size of the thermal bridge component.



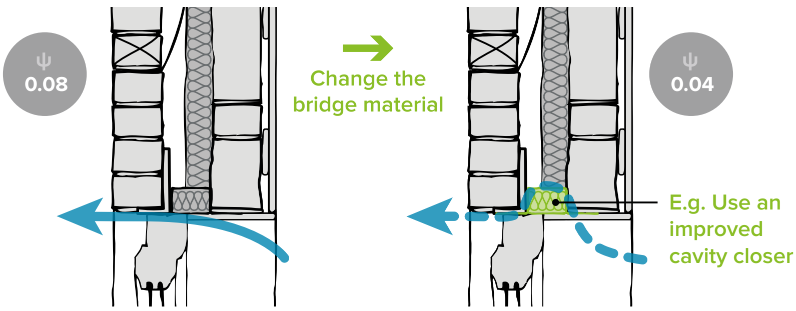
3. INCREASE THE THERMAL BRIDGE HEAT PATH

Increase the length of the thermal bridge or strategically place insulation in order to make the heat travel further to escape.



4. CHANGE THE THERMAL BRIDGE MATERIAL

Change the conductivity of the material causing the thermal bridge.



WHY IS THERMAL BRIDGING IMPORTANT?

If the fabric heat losses in SAP resulting from different building Y-values were to be replaced with a "hole in the wall" that produced equivalent heat loss it would look something like the end terrace example below.

THE BENEFITS OF JUNCTION IMPROVEMENT IN SAP

DWELLING Y-VALUES

The dwelling Y-value should be looked upon as a U-value for the whole building which aggregates all of the PSI-value junction losses. This 'thermal bridging U-value' is effectively added to each individual element U-value to yield the total fabric heat loss for the dwelling. For example, for a 0.15 Y-value dwelling:

Example	Element U-value	+	Thermal bridging Y-value	=	Overall fabric heat loss calculation		
					Combined U-value	x	Element area
Ext walls	0.21		0.15		0.36		Total ext wall area
Grd floor	0.15		0.15		0.30		Total grd floor area
Roof	0.13	+	0.15	=	0.28	x	Total roof area
Windows	1.4		0.15		1.55		Total window area
Doors	1.2		0.15		1.35		Total door area
					∑ Total fabric heat loss		

STRATEGIES FOR Y-VALUE REDUCTION

Strategies which reduce the fabric Y-values before improving fabric U-values are generally a more cost-effective means of reducing overall fabric heat losses. Examples of this so called 'PSI-first' approach to fabric improvement are illustrated in the following example on a typical masonry end terrace property, starting with a baseline solution using dense blockwork and perforated steel lintels and a default Y-value of 0.15 (no real consideration of junction PSI-values):

'PSI-first' strategy		Dwelling Y-value	Resulting SAP Fabric Solution					
Step	Action		Wall U-value	Grd floor U-value	Roof U-value	Window U-value	Door U-value	PV area
0	Baseline solution	0.15	0.15	0.12	0.1	1.4	1.2	$1.8m^2$
1	Change to split lintels throughout	0.11	0.15	0.12	0.1	1.4	1.2	$1.2m^2$
2	Change to low density blockwork inner leaf	0.08	0.18	0.12	0.1	1.4	1.2	$0.6m^2$
3	Misc additional minor junction improvements	0.06	0.18	0.14	0.12	1.4	1.2	$0m^2$

As can be seen, with a few changes to material specification preferences or detailing practice on certain key construction details can quickly diminish the need for renewable technologies or for onerous (and expensive) building fabric U-values. Numerous alternatives will exist to drive the overall building Y-value down, but the key is always to focus on the junctions which will have maximum significance on the dwelling in question (discussed further on p42), and on measures which deliver significant benefits (illustrated in the body of this Guide).

SAP BUILDING JUNCTIONS ILLUSTRATED

JUNCTIONS WITH AN EXTERNAL WALL

E1	Steel lintel with perforated steel base plate
E2	Other lintels (including other steel lintels)
E3	Sill
E4	Jamb
E5	Ground floor (normal)
E6	Intermediate floor within a dwelling
E7	Party floor between dwellings (in blocks of flats)
E8	Balcony within a dwelling, wall insulation continuous
E9	Balcony between dwellings, wall insulation continuous
E10	Eaves (insulation at ceiling level)
E11	Eaves (insulation at rafter level)
E12	Gable (insulation at ceiling level)
E13	Gable (insulation at rafter level)
E14	Flat roof
E15	Flat roof with parapet
E16	Corner (normal)
E17	Corner (inverted – internal area greater than external area)
E18	Party wall between dwellings
E19	Ground floor (inverted)
E20	Exposed floor (normal)
E21	Exposed floor (inverted)
E22	Basement floor
E23	Balcony support penetrates
E24	Eaves (insulation at ceiling level - inverted)
E25	Staggered party wall

JUNCTIONS WITH A PARTY WALL

P1	Ground floor
P2	Intermediate floor within a dwelling
P3	Intermediate floor between dwellings (in blocks of flats)
P4	Roof (insulation at ceiling level)
P5	Roof (insulation at rafter level)
P6	Ground floor (inverted)
P7	Exposed floor (normal)
P8	Exposed floor (inverted)

JUNCTIONS WITHIN A ROOF OR WITH A ROOM-IN-ROOF

R1	Head
R2	Sill
R3	Jamb
R4	Ridge (vaulted ceiling)
R5	Ridge (inverted)
R6	Flat ceiling
R7	Flat ceiling (inverted)
R8	Roof wall (rafter)
R9	Roof wall (flat ceiling)

KEY

Junctions with an external wall x

Junctions with a party wall x

Junctions within a roof or with a room-in-roof x

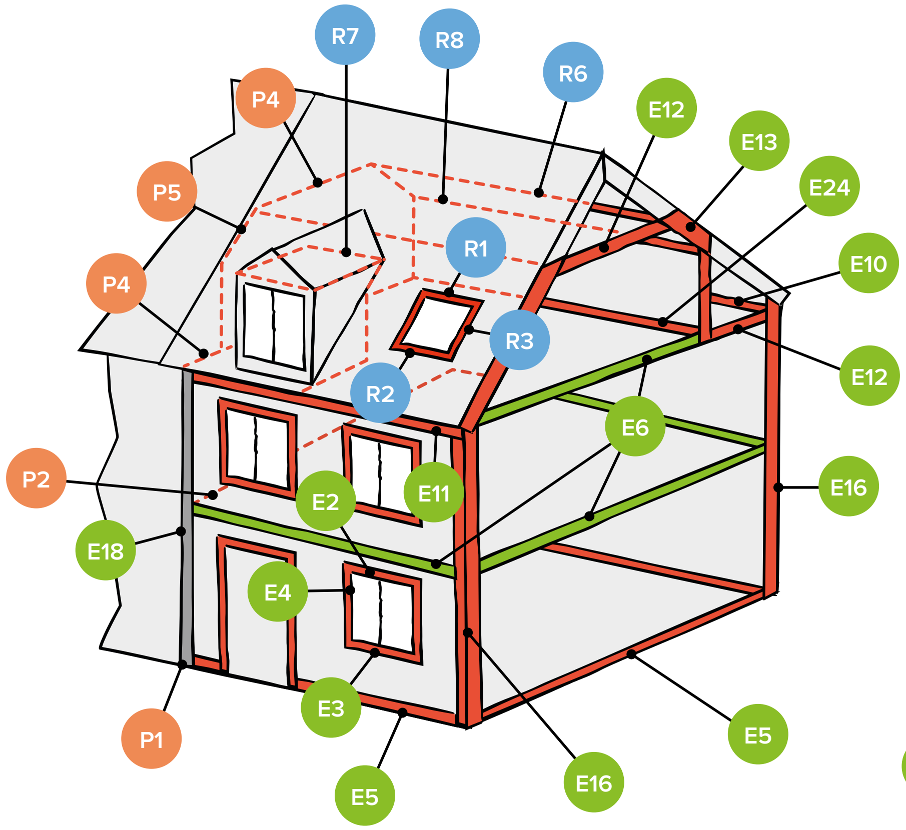
Insulated structure

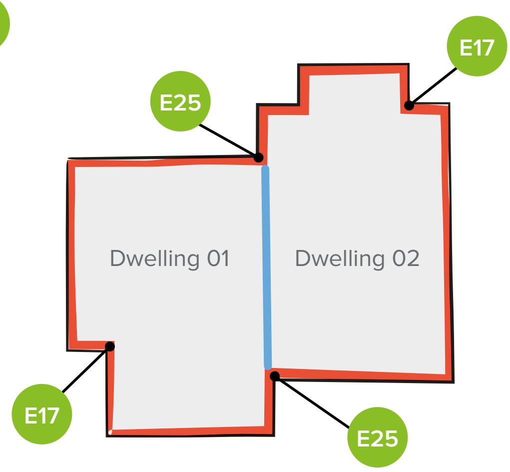
Heated Space

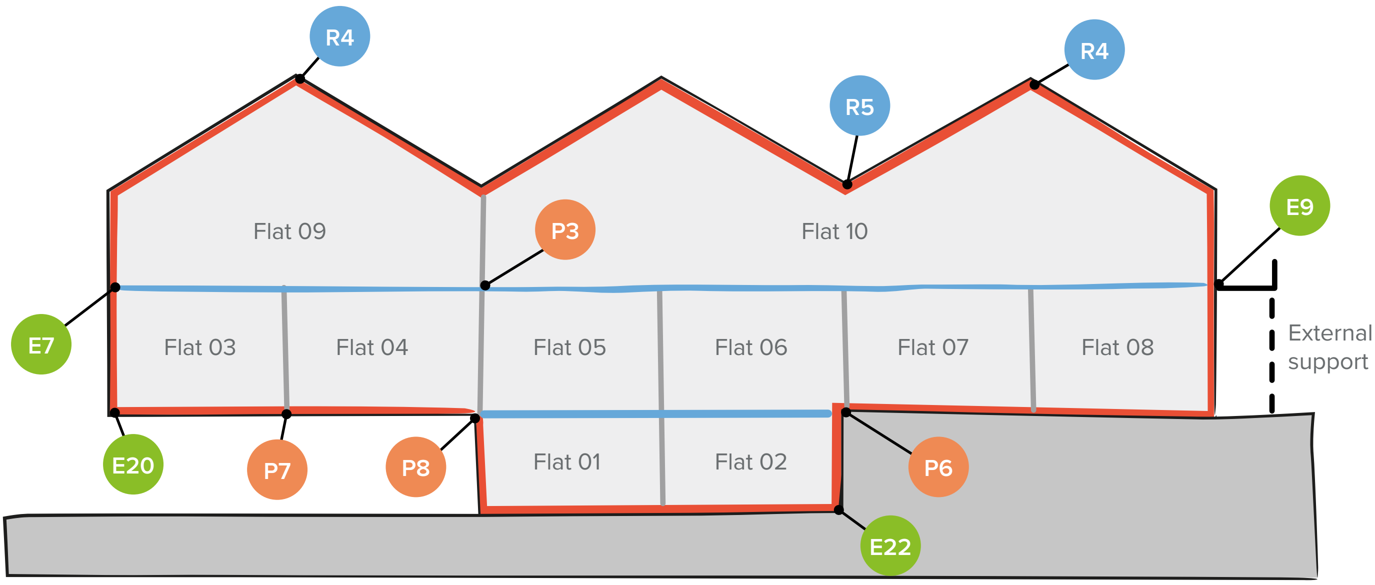
Internal floor

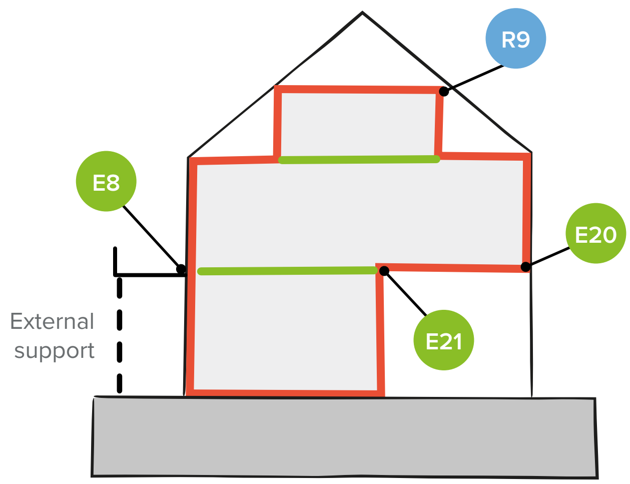
Party floor

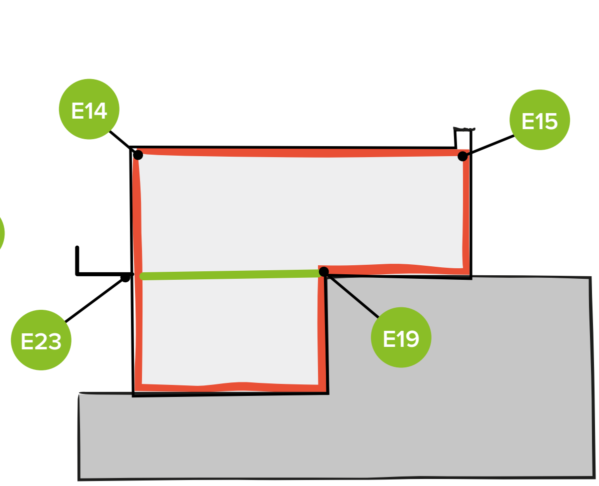
Party wall


R7
R8
R6
P4
E12
E13
E24
P5
R1
E10
P4
R3
E12
R2
E6
P2
E2
E11
E16
E18
E4
E3
E5
P1
E5
E16


E25
E17
Dwelling 01
Dwelling 02
E17
E25


R4
R4
R5
E9
Flat 09
P3
Flat 10
E7
Flat 03
Flat 04
Flat 05
Flat 06
Flat 07
Flat 08
External support
E20
P7
P8
Flat 01
Flat 02
P6
E22


R9
E8
E20
External support
E21


E14
E15
E23
E19

IDENTIFYING THE MOST SIGNIFICANT BUILDING JUNCTIONS

SAP REFERENCES

Table K1 of SAP 2012 includes a list of junction types. These have been illustrated on the preceding pages. Each junction has a reference e.g. E1, P4, R9.

Accompanying each Junction reference is a description of the detail and a default PSI-value to be used if an alternative more accurate value is not available.

Some junctions also have an “Approved” PSI-value (ACD) but these should be used with caution as they have not been updated since 2007 and must also be backed up by well documented QA check lists for site managers.

Other sources exist to obtain PSI-values for the building junctions of interest, as follows:

- Generic industry sponsored libraries covering the common building types e.g. LABC (http://www.labc.co.uk/registration-schemes/construction-details) or Scottish Standards (http://www.gov.scot/Topics/Built-Environment/Building/Building-standards/publications/pubtech)
- Individual product or building system manufacturer sponsored libraries, covering specific building products/systems, e.g. hollow block products or insulation manufacturers.
- Bespoke PSI-values calculated by 'competent persons' for specific developments.

*The 12 junctions **highlighted** are those identified opposite as the most important to consider for most dwellings.*

SAP Table K1: Values of PSI for different types of junctions

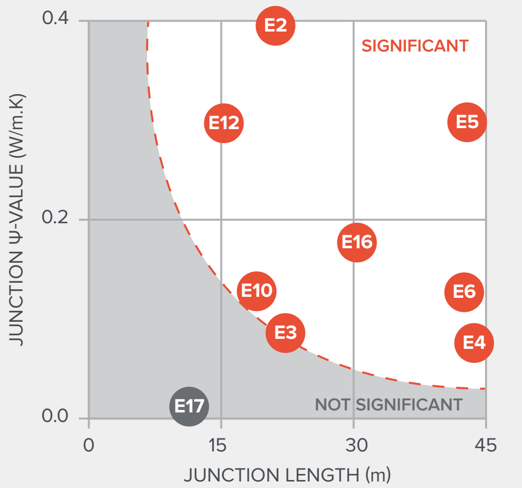
Ref	Junction detail	ACD	Default
Junctions with an external wall			
E1	Steel lintel with perforated steel base plate	0.5	1
E2	**Other lintels (including other steel lintels)**	0.3	1
E3	**Sill**	0.04	0.08
E4	**Jamb**	0.05	0.1
E5	**Ground floor (normal)**	0.16	0.32
E19	Ground floor (inverted)		0.07
E20	Exposed floor (normal)		0.32
E21	Exposed floor (inverted)		0.32
E22	Basement floor		0.07
E6	**Intermediate floor within a dwelling**	0.07	0.14
E7	**Party floor between dwellings (in flats)**	0.07	0.14
E8	Balcony within a dwelling, insulation continuous	0	0
E9	Balcony between dwellings, insulation continuous	0.02	0.04
E23	Balcony within or between dwellings, balcony support penetrates wall insulation		1
E10	**Eaves (insulation at ceiling level)**	0.06	0.12
E24	Eaves (insulation at ceiling level - inverted)	0.24	
E11	Eaves (insulation at rafter level)	0.04	0.08
E12	**Gable (insulation at ceiling level)**	0.24	0.48
E13	Gable (insulation at rafter level)	0.04	0.08
E14	Flat roof		0.08
E15	Flat roof with parapet		0.56
E16	**Corner (normal)**	0.09	0.18
E17	Corner (inverted – internal area greater than external area)	-0.09	0
E18	**Party wall between dwellings**	0.06	0.12
E25	Staggered party wall between dwellings	0.12	
Junctions with a party wall			
P1	**Ground floor**		0.16
P6	Ground floor (inverted)		0.07
P2	Intermediate floor within a dwelling		0
P3	Intermediate floor between dwellings (in flats)		0
P7	Exposed floor (normal)		0.16
P8	Exposed floor (inverted)		0.24
P4	**Roof (insulation at ceiling level)**		0.24
P5	Roof (insulation at rafter level)		0.08
Junctions within a roof or with a room-in-roof			
R1	Head		0.08
R2	Sill		0.06
R3	Jamb		0.08
R4	Ridge (vaulted ceiling)		0.08
R5	Ridge (inverted)		0.04
R6	Flat ceiling		0.06
R7	Flat ceiling (inverted)		0.04
R8	Roof wall (rafter)		0.06
R9	Roof wall (flat ceiling)		0.04

KEY BUILDING JUNCTIONS

Although SAP Table K1 lists over 40 different building junctions, many have extremely low default PSI-values and others occur rarely or over relatively short lengths in dwellings, so are of little significance in SAP. The most important junctions are those which either have high PSI-values, or occur frequently over significant lengths.

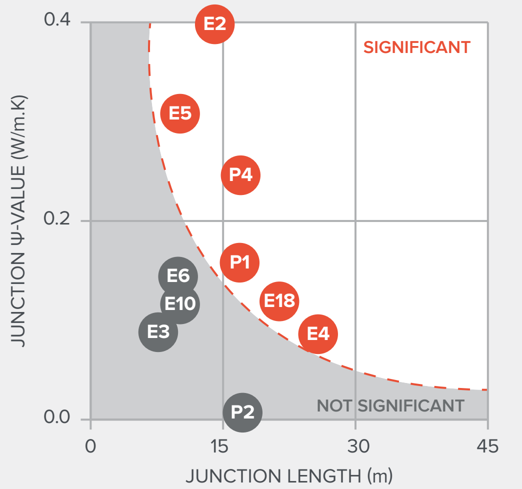
The charts below plot the PSI-value magnitudes relating to common building junctions and the typical length over which they occur in four types of dwelling. These charts thereby provide a simple means of identifying the key junction details which should be focused upon for each building type in order to control heat losses due to thermal bridging. These key building junctions are the focus of the main body of this Guide.

DETACHED HOUSE



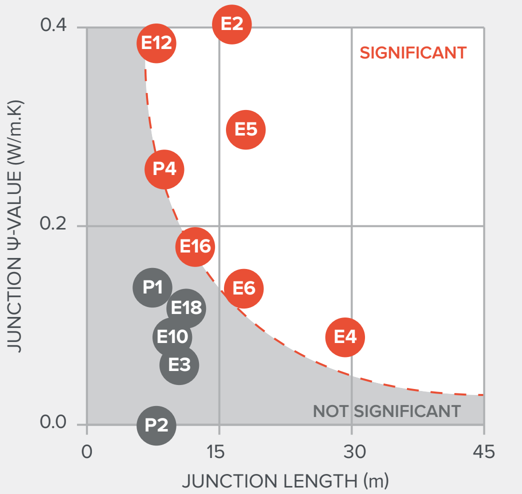
For detached houses the following details are the most important to focus on:
E2, E3, E4, E5, E6, E10, E12, E16
(approximately 90% of total junction heat loss)

MID TERRACE HOUSE



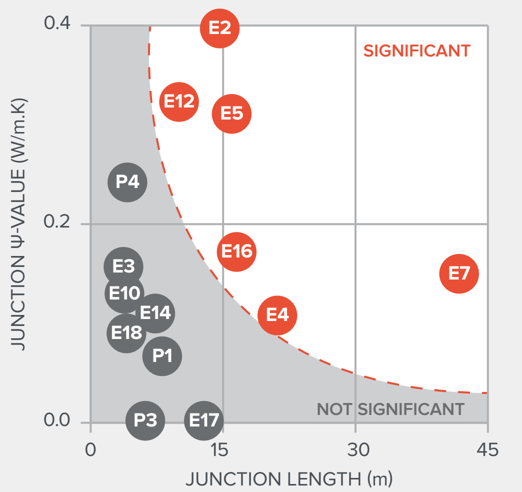
For mid terrace houses the following details are the most important to focus on:
E2, E4, E5, E18, P1, P4
(approximately 80% of total junction heat loss)

END TERRACE HOUSE



For end terrace houses the following details are the most important to focus on:
E2, E4, E5, E6, E12, E16, P4
(approximately 75% of total junction heat loss)

APARTMENT



For apartments the following details are the most important to focus on:
E2, E4, E5, E7, E12, E16
(approximately 80% of total junction heat loss)

PSI VALUE SENSITIVITY SUMMARIES
MASONRY CONSTRUCTION

Detail		SAP 2012 default PSI-value	Base detail PSI-value	Possible Problems						Design Options			
				1		2		3		1		2	
E2	Lintels – Perforated Steel	Ψ = 1.00	Ψ = 0.27	Misposition the frame from 30-0mm	Ψ = 0.310 15% worse	–		–		Insulate soffit/reveal	Ψ = 0.210 33% better	–	
E2	Lintel – Split lintel	Ψ = 1.00	Ψ = 0.08 split lintel	Omit the cavity closer	Ψ = 0.264 230% worse	Misposition the frame from 30-0mm	Ψ = 0.146 83% worse	Use an unbroken steel lintel	Ψ = 0.270 238% worse	Change frame overlap from 30-50mm	Ψ = 0.055 31% better	Use PIR/PU cavity closer	Ψ = 0.042 47% better
										Both: Ψ = 0.025, 69% better			
E3	Sill	Ψ = 0.08	Ψ = 0.05	Omit the cavity closer	Ψ = 0.150 200% worse	Misposition the frame from 30-0mm	Ψ = 0.085 70% worse	–		Change frame overlap from 30-50mm	Ψ = 0.035 30% better	Use PIR/PU cavity closer	Ψ = 0.034 32% better
										Both = Ψ = 0.025, 50% better			
E4	Jamb	Ψ = 0.10	Ψ = 0.05	Omit the cavity closer	Ψ = 0.115 130% worse	Misposition the frame from 30-0mm	Ψ = 0.120 140% worse	–		Change frame overlap from 30-50mm	Ψ = 0.035 30% better	Use PIR/PU cavity closer	Ψ = 0.034 32% better
										Both: Ψ = 0.025, 50% better			
E5	Ground floor – ground bearing	Ψ = 0.32	Ψ = 0.17 dense aggregate	Omit floor perimeter insulation	Ψ = 0.230 35% worse	Omit cavity insulation below dpc	Ψ = 0.316 86% worse	–		Change footing blocks to light aggregate	Ψ = 0.145 15% better	Change inner leaf blockwork to light aggregate	Ψ = 0.060 65% better
E5	Ground floor – beam & block	Ψ = 0.32	Ψ = 0.16 dense aggregate	Omit floor perimeter insulation	Ψ = 0.192 20% worse	Omit cavity insulation below dpc	Ψ = 0.258 61% worse	–		Change footing blocks to light aggregate	Ψ = 0.152 5% better	Change inner leaf blockwork to light aggregate	Ψ = 0.045 72% better
E6	Intermediate floor Timber	Ψ = 0.14	Ψ = 0.00	–		–		–		Note very punitive default value - Use any modelled value		–	
E7	Party floor – PCC slab	Ψ = 0.14	Ψ = 0.05	–		–		–		Note very punitive default value - Use any modelled value		–	
E10	Eaves insulated at ceiling	Ψ = 0.12	Ψ = 0.06 45° pitch	Omit ceiling eaves insulation	Ψ = 0.540 800% worse	Omit soffit insulation at eaves	Ψ = 0.360 500% worse	–		Increase rafter eaves insulation depth from 100-150mm	Ψ = 0.040 33% better	Use thermal laminate plasterboard	Ψ = 0.040 33% better
E12	Gable insulated at ceiling	Ψ = 0.48	Ψ = 0.20 dense aggregate	Omit roof perimeter insulation between truss and wall	Ψ = 0.580 190% worse	Omit cavity insulation above ceiling level	Ψ = 0.390 95% worse	–		Change inner leaf blockwork to light aggregate	Ψ = 0.075 62% better	Use thermal laminate plasterboard	Ψ = 0.120 40% better
E16	External corner	Ψ = 0.18	Ψ = 0.06	–		–		–		Note very punitive default value - Use any modelled value		–	
E18	Party wall	Ψ = 0.12	Ψ = 0.05	–		–		–		Note very punitive default value - Use any modelled value		–	
P1	Party wall foot – ground bearing	Ψ = 0.16	Ψ = 0.14 dense aggregate	Omit floor perimeter insulation	Ψ = 0.172 23% worse	Omit cavity insulation below dpc	Ψ = 0.153 9% worse	–		Change footing blocks to light aggregate	Ψ = 0.129 8% better	Change inner leaf blockwork to light aggregate	Ψ = 0.057 59% better
P1	Party wall foot – beam & block	Ψ = 0.16	Ψ = 0.19 dense aggregate	Omit floor perimeter insulation	Ψ = 0.210 11% worse	Omit cavity insulation below dpc	Ψ = 0.205 8% worse	–		Change footing blocks to light aggregate	Ψ = 0.181 5% better	Change inner leaf blockwork to light aggregate	Ψ = 0.057 70% better
P4	Party wall head	Ψ = 0.24	Ψ = 0.20 dense aggregate	Omit roof perimeter insulation between truss and wall	Ψ = 0.590 195% worse	Omit cavity insulation above ceiling level	Ψ = 0.400 100% worse	–		Change inner leaf blockwork to light aggregate	Ψ = 0.058 71% better	Use thermal laminate plasterboard	Ψ = 0.160 20% better

PSI VALUE SENSITIVITY SUMMARIES

TIMBER FRAME CONSTRUCTION

Detail		SAP 2012 default PSI-value	Base detail PSI-value	Possible Problems 1		Possible Problems 2		Design Options 1		Design Options 2		Design Options 3		Extra Insulation position: Outside	Extra Insulation position: Inside
E2	Timber Lintel	Ψ = 1.0	Ψ = 0.15	Omit insulation in lintel cavity	Ψ = 0.180 20% worse	Misposition the frame from 30-0mm	Ψ = 0.221 47% worse	Use 25mm thermal laminate plasterboard in reveal/soffit	Ψ = 0.095 37% better	Change frame overlap from 30-50mm	Ψ = 0.131 13% better	Use PIR/PU in lintel cavity	Ψ = 0.140 7% better	Ψ = 0.131 13% better	Ψ = 0.135 10% better
E3	Sill	Ψ = 0.08	Ψ = 0.07	Omit the cavity closer	Ψ = 0.087 24% worse	Misposition the frame from 30-0mm	Ψ = 0.107 53% worse			Change frame overlap from 30-50mm	Ψ = 0.055 21% better	Use PIR/PU cavity closer	Ψ = 0.060 14% better	Ψ = 0.070 0%	Ψ = 0.068 3% better
E4	Jamb	Ψ = 0.1	Ψ = 0.10	Omit the cavity closer	Ψ = 0.133 33% worse	Misposition the frame from 30-0mm	Ψ = 0.150 50% worse	Use 25mm thermal laminate plasterboard in reveal/soffit	Ψ = 0.055 45% better	Change frame overlap from 30-50mm	Ψ = 0.084 16% better	Use PIR/PU cavity closer	Ψ = 0.088 12% better	Ψ = 0.086 14% better	Ψ = 0.096 4% better
E5	Ground floor – ground bearing slab	Ψ = 0.32	Ψ = 0.20 dense aggregate	Omit perimeter insulation	Ψ = 0.500 150% worse	–		Change perimeter insulation thickness from 25-50mm	Ψ = 0.155 22% better	Change footing blocks to light aggregate	Ψ = 0.145 27% better	–		Ψ = 0.212 6% worse	Ψ = 0.168 16% better
E5	Ground floor – beam & block	Ψ = 0.32	Ψ = 0.14 dense aggregate	Omit perimeter insulation	Ψ = 0.300 114% worse	–		Change perimeter insulation thickness from 25-50mm	Ψ = 0.111 21% better	Change footing blocks to light aggregate	Ψ = 0.111 21% better	–		Ψ = 0.155 11% worse	Ψ = 0.050 64% better
E6	Intermediate Floor	Ψ = 0.14	Ψ = 0.11	Omit rim board insulation	Ψ = 0.262 138% worse	–		Change insulation behind rim board from 75-150mm	Ψ = 0.080 27% better	Use 25mm thermal laminate plasterboard on inside of frame	Ψ = 0.090 18% better	–		Ψ = 0.034 69% better	Ψ = 0.086 22% better
E7	Party Floor	Ψ = 0.14	Ψ = 0.07	–		–		–		–		–		Ψ = 0.062 6% better	Ψ = 0.064 3% better
E10	Eaves insulated at ceiling	Ψ = 0.12	Ψ = 0.04 45° pitch	Omit ceiling eaves insulation	Ψ = 0.210 425% worse	Omit soffit insulation at eaves	Ψ = 0.085 112% worse	Increase ceiling eaves insulation depth from 100-150mm	Ψ = 0.030 25% better	Use 25mm thermal laminate plasterboard on inside of frame	Ψ = 0.030 25% better	–		Ψ = 0.065 63% worse	Ψ = 0.030 25% better
E12	Gable insulated at ceiling	Ψ = 0.48	Ψ = 0.07	–		–		Note very punitive default value - Use any modelled value		–		–		Ψ = 0.045 36% better	Ψ = 0.053 24% better
E16	External corner	Ψ = 0.18	Ψ = 0.05	–		–		–		–		–		Ψ = 0.055 8% worse	Ψ = 0.046 8% better
E18	Party wall	Ψ = 0.12	Ψ = 0.04	–		–		–		–		–		Ψ = 0.033 17% better	Ψ = 0.034 16% better
P1	Party wall foot – ground bearing slab	Ψ = 0.16	Ψ = 0.10 dense aggregate	Omit perimeter insulation	Ψ = 0.162 62% worse	–		Change perimeter insulation thickness from 25-50mm	Ψ = 0.086 14% better	Change footing blocks to light aggregate	Ψ = 0.048 52% better	–		–	–
P1	Party wall foot – beam & block	Ψ = 0.16	Ψ = 0.10 dense aggregate	Omit perimeter insulation	Ψ = 0.183 83% worse	–		Change perimeter insulation thickness from 25-50mm	Ψ = 0.089 11% better	Change footing blocks to light aggregate	Ψ = 0.048 52% better	–		–	–
P4	Party wall head	Ψ = 0.24	Ψ = 0.02	–		–		Note very punitive default value - Use any modelled value		–		–		–	–

NOTES

NOTE: This Guide is not a legal document and does not form part of a Building Regulations approved specification. It is for information and good practice purposes only. Consult your Building Control Officer for details on approved specification's and policy.

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