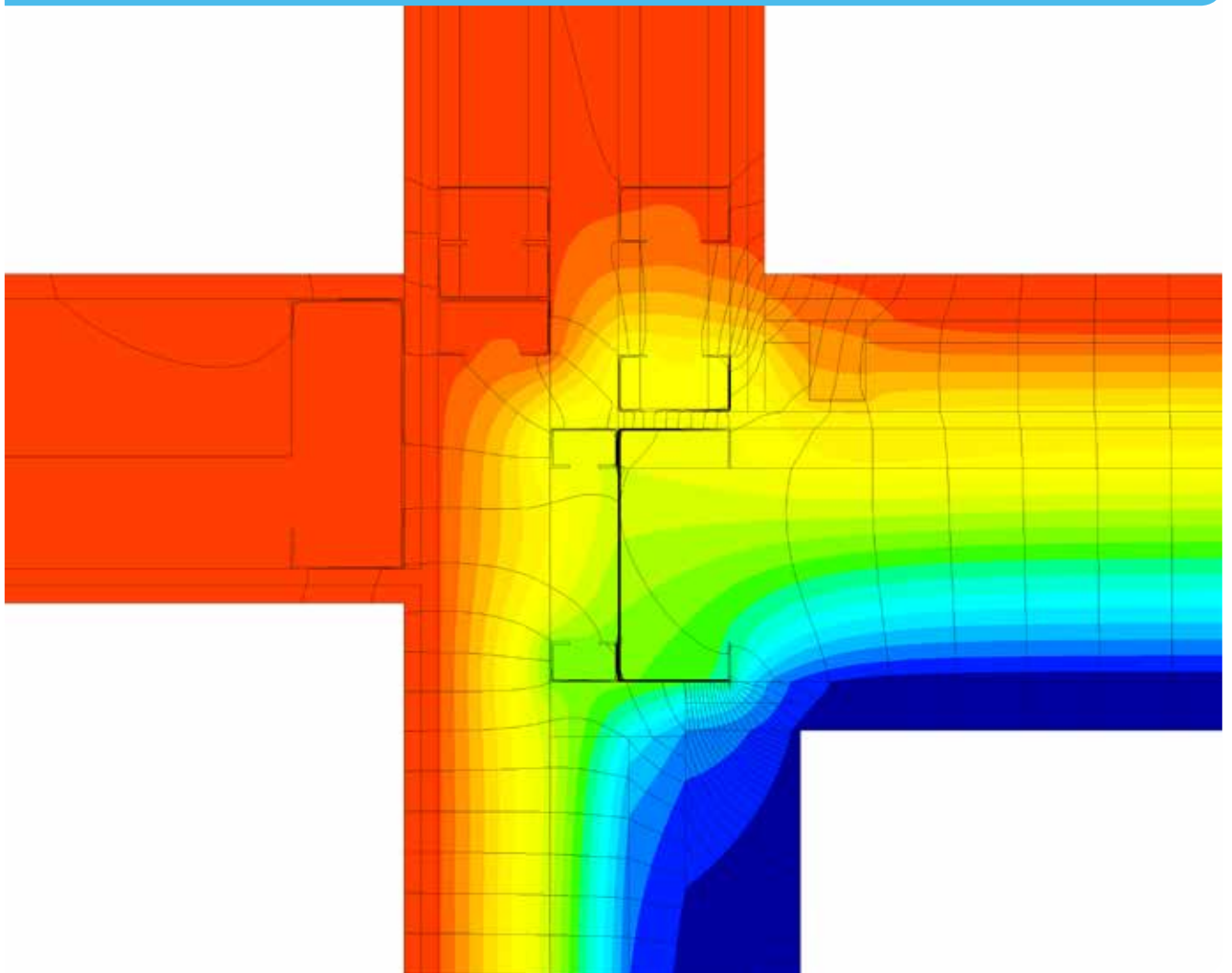


Second edition

# Conventions for calculating linear thermal transmittance and temperature factors

Tim Ward, Graeme Hannah and Chris Sanders





# Conventions for calculating linear thermal transmittance and temperature factors

Tim Ward, Graeme Hannah and Chris Sanders\*

\* Glasgow Caledonian University

The research and writing for this publication has been funded by BRE Trust, the largest UK charity dedicated specifically to research and education in the built environment. BRE Trust uses the profits made by its trading companies to fund new research and education programmes that advance knowledge, innovation and communication for public benefit.

**BRE Trust** is a company limited by guarantee, registered in England and Wales (no. 3282856) and registered as a charity in England (no. 1092193) and in Scotland (no. SC039320). Registered office: Bucknalls Lane, Garston, Watford, Herts WD25 9XX  
Tel: +44 (0) 333 321 8811  
Email: [secretary@bretrust.co.uk](mailto:secretary@bretrust.co.uk)  
[www.bretrust.org.uk](http://www.bretrust.org.uk)

**IHS (NYSE: IHS)** is the leading source of information, insight and analytics in critical areas that shape today's business landscape. Businesses and governments in more than 165 countries around the globe rely on the comprehensive content, expert independent analysis and flexible delivery methods of IHS to make high-impact decisions and develop strategies with speed and confidence. IHS is the exclusive publisher of BRE publications.

IHS Global Ltd is a private limited company registered in England and Wales (no. 00788737). Registered office: The Capitol Building, Oldbury, Bracknell, Berkshire RG12 8FZ. [www.ihs.com](http://www.ihs.com)

BRE publications are available from [www.brebookshop.com](http://www.brebookshop.com) or  
IHS BRE Press  
The Capitol Building  
Oldbury  
Bracknell  
Berkshire RG12 8FZ  
Tel: +44 (0) 1344 328038  
Fax: +44 (0) 1344 328005  
Email: [brepress@ihs.com](mailto:brepress@ihs.com)

© IHS 2016. No part of this publication may be reproduced or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, or be stored in any retrieval system of any nature, without prior written permission of IHS. Requests to copy any part of this publication should be made to:

The Publisher  
IHS  
Verulam Point  
Station Way  
St Albans  
Herts AL1 5HE  
Tel: +44 (0) 1727 733810  
Email: [brepress@ihs.com](mailto:brepress@ihs.com)

Printed using FSC or PEFC material from sustainable forests.

**BR 497**  
First published 2007  
Second edition 2016  
ISBN 978-1-84806-440-9

Any third-party URLs are given for information and reference purposes only and BRE and IHS do not control or warrant the accuracy, relevance, availability, timeliness or completeness of the information contained on any third-party website. Inclusion of any third-party details or website is not intended to reflect their importance, nor is it intended to endorse any views expressed, products or services offered, nor the companies or organisations in question.

Any views expressed in this publication are not necessarily those of BRE or IHS. BRE and IHS have made every effort to ensure that the information and guidance in this publication were accurate when published, but can take no responsibility for the subsequent use of this information, nor for any errors or omissions it may contain. To the extent permitted by law, BRE and IHS shall not be liable for any loss, damage or expense incurred by reliance on the information or any statement contained herein.

The first edition of this report was produced as part of the research programme of the Sustainable Buildings Division of the Department for Communities and Local Government. This revision was produced as part of the research programme of the BRE Trust.

**Any updates to the guidance given in this publication will be posted at [www.bre.co.uk/br497updates](http://www.bre.co.uk/br497updates)**

# Contents

Abbreviations and notation	v
<b>1 Introduction</b>	<b>1</b>
<b>2 Numerical modelling</b>	<b>2</b>
2.1 Two- or three-dimensional modelling	2
2.2 Specification of the numerical model	2
2.2.1 <i>General principles</i>	2
2.2.2 <i>Extent of the model</i>	2
2.2.3 <i>Adjacent thermal bridges</i>	2
2.2.4 <i>Non-rectangular elements</i>	3
2.2.5 <i>Large spaces with an intermediate temperature between the internal and external environment</i>	3
2.2.6 <i>Substitution of window and door frames with adiabatic boundary layers</i>	4
2.3 Thermal conductivities of materials	4
2.3.1 <i>Perforated metal plates</i>	4
2.4 Treatment of air spaces	4
2.4.1 <i>Air space resistances</i>	5
2.4.2 <i>Regular divided air spaces</i>	5
2.4.3 <i>Irregular divided air spaces</i>	5
2.4.4 <i>Narrow extended air spaces</i>	6
2.5 Surface heat transfer (surface resistances)	7
2.6 Refining the mesh size	7
2.7 Reporting of temperatures and heat flows	8
<b>3 Thermal bridging at junctions</b>	<b>9</b>
3.1 $\Psi$ -value	9
3.1.1 <i>Definition</i>	9
3.1.2 <i>Areas over which U-values are applied</i>	9
3.1.3 <i>Modelling U-value, <math>U'</math></i>	10
3.1.4 <i>Alternative expression for calculating <math>\Psi</math></i>	11
3.2 Temperature factor, $f_{Rsj}$	12
3.2.1 <i>Temperature factors for ground-floor junctions</i>	12
<b>4 Junction types</b>	<b>13</b>
4.1 Roof junctions	13
4.1.1 <i>Roof eaves (insulated at ceiling)</i>	13
4.1.2 <i>Roof gable (insulated at ceiling)</i>	14
4.1.3 <i>Roof/party wall (insulated at ceiling)</i>	14
4.1.4 <i>Roof eaves (insulated on slope)</i>	15
4.1.5 <i>Roof gable (insulated on slope)</i>	15
4.1.6 <i>Roof/party wall (insulated at roof level)</i>	16
4.1.7 <i>Flat-roof eaves</i>	16
4.1.8 <i>Flat-roof parapet</i>	16

4	Junction types ( <i>cont'd</i> )	
4.2	Room-in-roof junctions	17
4.2.1	Ridge ( <i>vaulted ceiling</i> )	17
4.2.2	Ridge ( <i>vaulted ceiling – inverted</i> )	17
4.2.3	Sloping rafter to flat ceiling ( <i>insulated at ceiling</i> )	17
4.2.4	Flat ceiling to rafter slope ( <i>inverted</i> )	17
4.2.5	Roof wall to rafter	18
4.2.6	Roof wall to flat ceiling	18
4.3	Junctions around openings	18
4.3.1	Lintel ( <i>window head</i> )	18
4.3.2	Jamb	19
4.3.3	Sill	19
4.3.4	Rooflight	19
4.4	Corner junctions	19
4.4.1	Corner ( <i>normal</i> )	19
4.4.2	Corner ( <i>inverted</i> )	20
4.4.3	Staggered party wall ( <i>horizontal</i> )	20
4.5	Intermediate-floor or party-wall junctions (with external wall)	20
4.5.1	Intermediate floor	20
4.5.2	Balcony	21
4.5.3	Partition/party wall	21
4.6	Exposed floors	22
4.6.1	Exposed floor ( <i>normal</i> )	22
4.6.2	Exposed floor ( <i>inverted</i> )	22
4.7	Ground-floor junctions	22
4.7.1	Solid ground floor	22
4.7.2	Suspended ground floor	23
4.7.3	Basement wall/floor junction	23
4.8	Special-case junctions that connect to the ground	24
4.8.1	Party wall/ground-floor junction	24
4.8.2	Party wall/ground-floor ( <i>inverted</i> ) junction	26
4.8.3	Ground floor ( <i>inverted</i> )	28
5	Point thermal bridges, $\chi$ -values	30
6	Reporting of calculations	31
7	References	32
	Appendices	33
A	Detailed input and output from a numerical model	34
B	Worked examples with calculated values of $\Psi$ and $f$	35
	Worked example 1 – E10: Eaves (pitched roof insulated at ceiling)	36
	Worked example 2 – R6: Roof (sloping rafter to flat ceiling)	37
	Worked example 3 – E1: Steel lintel with perforated steel base-plate	38
	Worked example 4 – E25: Staggered party wall between dwellings	40
	Worked example 5 – E23: Balcony between dwellings, balcony support penetrates wall insulation	41
	Worked example 6 – E21: Exposed floor ( <i>inverted</i> )	42
	Worked example 7 – E5: Suspended ground floor	43
	Worked example 8 – E22: Basement wall/floor junction	46
	Worked example 9 – P1: Party wall/ground-floor junction	47
	Worked example 10 – P6: Party wall/ground-floor ( <i>inverted</i> ) junction	48

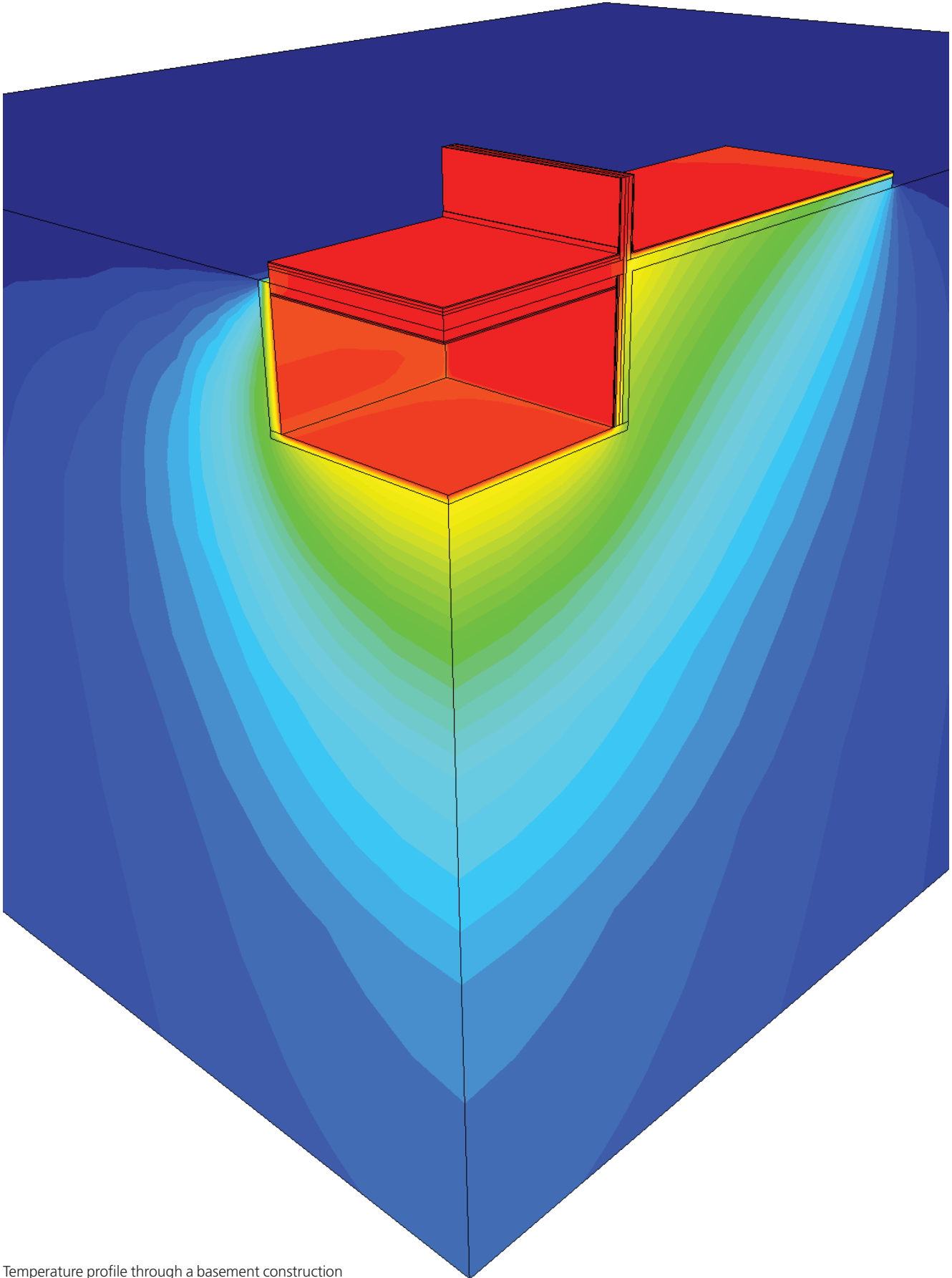
# Abbreviations and notation

## Abbreviations

dpc	damp proof course
dpm	damp proof membrane
low-e	low emissivity
P/A	perimeter divided by area ratio
1D	one dimension/one-dimensional
2D	two dimensions/two-dimensional
3D	three dimensions/three-dimensional

## Notation

A	area
b	width
$\beta$	angle of slope
$\chi$	point thermal transmittance
d	thickness
e	external environment
<i>f</i>	temperature factor
h	height
$h_{se}$	heat transfer coefficient of external surface
$h_{si}$	heat transfer coefficient of inside surface
H	heat transfer factor
i	internal environment
L	thermal coupling coefficient
$\ell$	length in metres over which U applies
n	number of units
Q	total heat flow
$R_{se}$	thermal resistance of external surface
$R_{si}$	thermal resistance of inside surface
T	temperature
U	U-value
w	width
$\Psi$	linear thermal transmittance



Temperature profile through a basement construction and the adjacent ground

# 1 Introduction

Global warming, with the need to limit CO<sub>2</sub> emissions into the atmosphere, is the principal driver for conserving fuel and power in buildings. Confirmation that this is very much part of the UK Government's agenda is found in the successive changes to Part L of the Building Regulations in England<sup>[1]</sup> and Wales<sup>[2]</sup>, with similar changes to the equivalent sections in Scotland<sup>[3]</sup> and Northern Ireland<sup>[4]</sup>.

The introduction of more highly insulated buildings, that has resulted from the need to save energy, has also led to the need for more sophisticated methods for calculating heat loss and surface temperatures than were previously felt to be adequate. Two changes are particularly important:

- While U-values of the building fabric could previously be calculated by assuming that an element was made up of a series of parallel layers, each with uniform thermal resistance, it is now recognised that features such as mortar joints, timber studs or the metal spacers in built-up roofs cause thermal bridging of the insulation layer(s) and so contribute significantly to the heat loss. A more detailed calculation method for U-values, as defined in BS EN ISO 6946:2007<sup>[5]</sup>, has been introduced to take account of these repeating thermal bridges.
- It has also been recognised that thermal bridging at the junctions between the various plane building elements (walls, roofs and floors) of a building and those around openings in walls and roofs can add significantly to the fabric heat loss. The higher heat flows that occur, because of complex geometries or the use of materials with a high thermal conductivity, also cause localised reduction in the internal surface temperatures, which in turn can lead to surface condensation and mould problems.

Although various simplified calculation methods have been developed to take account of the effects of thermal bridging in certain situations, two- or three- dimensional heat flow calculations continue to be required for *some* U-value and for *most* (non-repeating) thermal bridge calculations. These calculations of two- or three-dimensional heat flow require the use of numerical modelling software. Several packages are available but, whereas most software packages themselves are validated as being able to produce correct and consistent results, many important decisions are left to the user regarding the input to the modelling software and the determination of certain quantities from the output of the software, both of which can have a significant effect on the results.

This BRE guide (BR 497) gives the information needed to carry out these calculations so that different users of the same software package and users of different software packages can obtain consistent results. However, *before using the conventions* given in BR 497 it is important for the numerical modeller to demonstrate that the numerical modelling software used can model the validation examples in BS EN ISO 10211:2007<sup>[6]</sup> with results that agree with the stated values of temperature and heat flow within the tolerance indicated in the standard for each appropriate validation example.

BR 497 has been prepared to complement the outline methodology for the treatment of thermal bridges given in BRE Information Paper IP 1/06<sup>[7]</sup>. It can be used by assessors who wish to undertake numerical modelling calculations to determine the thermal performance of junctions. It is referenced in the relevant government policy documents operating in England, Scotland, Wales, Northern Ireland and the Republic of Ireland.