[European projects]

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Good practice guidance should contain:

> Well illustrated introduction to what thermal bridges are, their effects, and the main principles of avoiding them
> Well-illustrated examples of serious thermal bridges, and their solutions
> Routes to compliance:

Routes to compliance should also be supported by:

> Established clearly-defined simple quantitative levels of good practice (e.g. minimum thickness of thermal breaks)
> Collections of detailed drawings showing good solutions, together with their thermal bridge values
> Calculation methods for alternative details

Good practice guidance on thermal bridges & construction details, *Part I: Principles*

Most areas of Europe need good thermal insulation in order to conserve energy and to improve indoor climate. Minimizing thermal bridges is an important part of achieving this. However, even in well-insulated buildings, thermal bridges are often neglected.

This paper suggests topics that should covered in ‘good practice’ guidance, how it can be structured and presented, and how it can be related to building regulations and standardization. Part II of the paper shows a selection of good examples from different countries.

This paper is published together with an electronic archive (file *thermal_bridge_good_practice.ZIP*) containing over 60 reference documents. This paper has clickable hyperlinks for opening the individual documents. The ZIP file contents should be extracted to the same directory as this PDF for the hyperlinks to work.

The target readership for this paper is organizations planning to publish or update their own construction details and guidance on thermal bridges & airtightness. It is also aimed at building authorities, standardization bodies, and energy agencies.

1 > HOW TO STRUCTURE & DISSEMINATE GUIDANCE, AND INTEGRATE IT INTO REGULATIONS & STANDARDS

Widespread dissemination, and tight integration with building regulations & standardization, are crucial to successful adoption of higher building standards. Guidelines on thermal bridges should therefore be:

> …available in both paper & electronic media (free or low cost on Internet), both as a complete handbook and as separate construction details. Comprehensive examples of are UK [*UK01*] and Ireland [*IE01*].
> …referenced from the national building regulations and the national energy performance calculation standard. In conjunction with this, the country should establish the following:
  — The national energy performance regulations should require/assume a minimum or ‘default’ standard of thermal bridge heat loss (e.g. ΔU or Ψ'', W/m²K per unit façade area or floor area). This can be supported by a collection of ‘preaccepted’ construction details that achieve this standard. An example of this is UK’s *Accredited Construction Details* [*UK01*]. The same can be done for optional higher standards, such as the UK’s *Enhanced Construction Details* [*UK02*, *UK03*], or passive house standard details [*AT01*, *AT02*,

[BE02]. Minimum standards should also be defined to limit, for example, condensation risk.

— A national standard defining:

(a) ...calculation of areas for thermal transmission (Fig.1). The two main alternatives are *internal* or *external* areas. Both are acknowledged in the International Standard for calculation of thermal bridges [EN ISO 10211]. This has consequences for the numerical values of geometric thermal bridges. Using *external areas* is a safer (more conservative) approach because it leads to smaller linear thermal transmittances for external edges than if internal dimensions are used (Fig.10b), hence less error if the thermal bridges were ignored. However, *internal areas* are more practical, and easier to calculate. For example, it avoids the uncertainty in outer area for e.g. ventilated cavities, double facades, complex external geometry and sloped roofs. Furthermore, most thermal bridges are not purely geometric, so the benefit of using external areas is not so great.

(b) ...which types of thermal bridges should be aggregated into normal U-values for facades, and which should be kept separate as thermal bridge Ψ-values. There is international consensus on this issue:

- All framework (studs and top & sole plates) and extra framework around window & door frames (sill plate, king & trim studs, and headers; see Figs 4 & 5) and other repeating thermal bridges in the facade, should generally be aggregated into *U*-values. Thus, *U*-values should reflect the true amount of framework (i.e. length of framework per m² opaque wall), which can vary greatly depending on window geometry and area.
- This leaves only geometric thermal bridges (e.g corners), and non-repeating thermal bridges (e.g. around ground slab) that should be evaluated with separate thermal bridge calculations.

— Examples of standards are Danish DS 418 [DK01 summarized in DK02], German DIN 4108 [DE01], and Dutch NEN 1068 [NL01] & NPR 2068 [NL02].

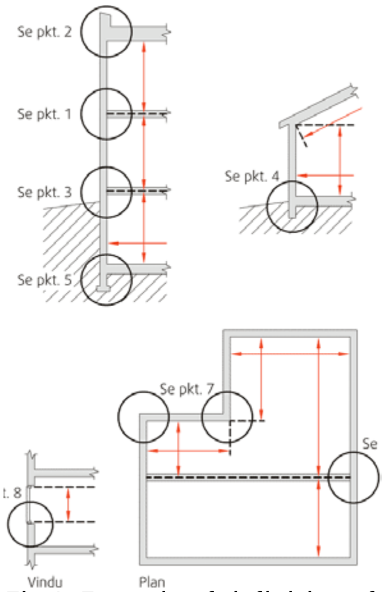

Fig.1 Example of definition of internal dimensions. Thermal bridges are circled [© SINTEF]

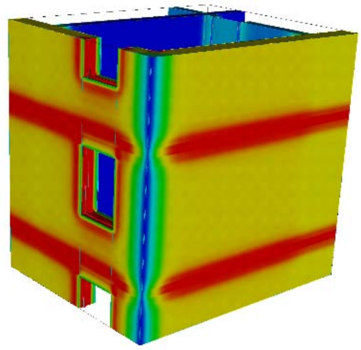

Fig.2 3D finite-element model calculation of heat loss. Red is highest heat flux.

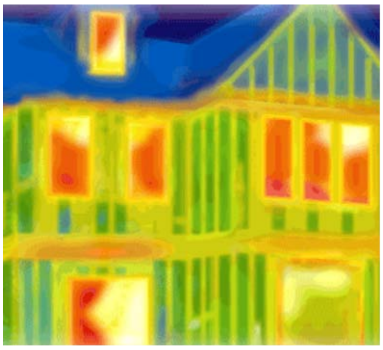

Fig.3 Thermal camera image of timber frame walls.

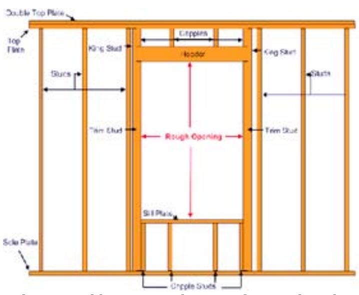

Fig.4 Illustration of typical wood framework with window.

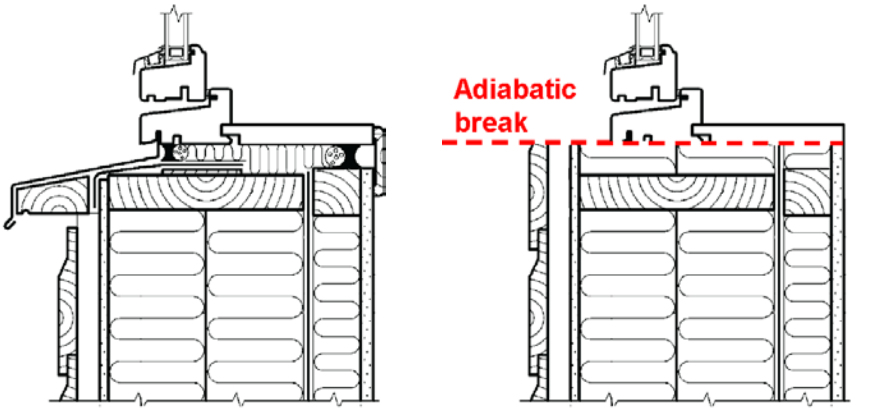

Fig.5 The magnitude of the window/wall thermal bridge is the difference in heat loss between these two pictures. Wall framework is accounted for in the wall's U-value, but heat loss through it increases when it is in thermal contact with the window frame (left) [source: SINTEF]

2 > TOPICS TO COVERED BY GUIDANCE HANDBOOKS

(a) Concise introduction to thermal bridges, and their avoidance

> *What functions must façade details fulfil?*: The reader should first be made aware of the functional requirements to take into consideration

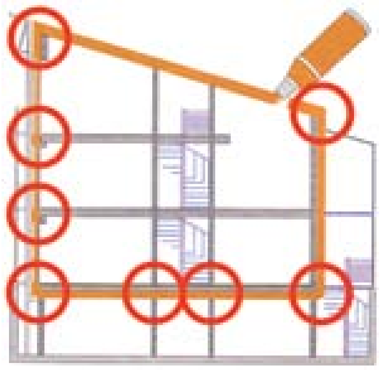

Fig.6 Aim for continuous thermal insulation. Imagine drawing an unbroken line around the building envelope. Red circles indicate thermal bridges [source: PHI]

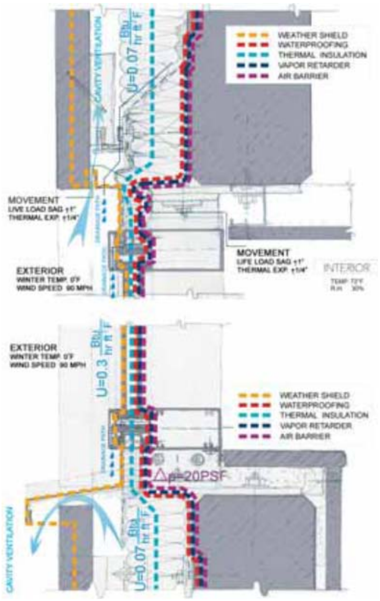

Fig.7 The principle of ensuring continuity of layering past windows, incl. thermal insulation. [source CA01]

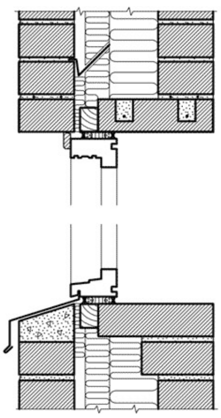

Fig.8 Position windows in line with the insulation layer, and the upturned edge of the windowsill flashing should be just outside insulation layer. [© SINTEF]

when designing construction details. See Fig.9 below. The most important are weatherproofing, airtightness, thermal insulation and vapour barrier. The ordering of the different layers is important. This is well described in [CA01 page 20-23].

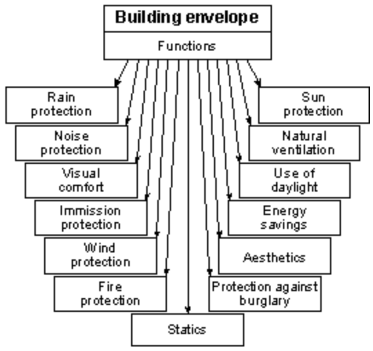

Fig.9 Functional requirements of building envelopes [source: IBP]

> *What is a thermal bridge?*: Generally it is part of a building façade where heat-conducting materials come in contact, creating a 'short-circuit' heat flow path though the facade. Thermal bridges are characterized by multi-dimensional heat flow such that the local heat loss deviates from the façade's assumed U-value.

> *Types of thermal bridges*:
> (**a**) **Repeating**, e.g. wall studs and ties, which can be accounted for in U-values (Fig.3 & 4), (**b**) **Non-repeating**, e.g. details around windows & doors, cantilevered balconies, or junctions between façade areas (Fig.10a & red areas of Fig.2), (**c**) **Geometric**, i.e. angled intersection of two planes, which leads to a difference in area of the outside and inside surfaces of the façade (e.g. Fig.10b & blue corner of Fig.2)

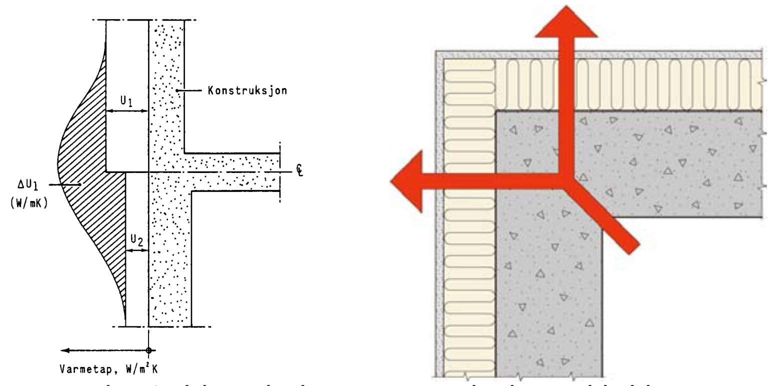

Fig.10 (a) Typical non-geometric thermal bridge, (b) geometric thermal bridge at an external corner. The thermal bridge value Ψ (W/mK) is negative if the heat loss calculation (U•A) is based on external area, and is positive if A is internal area [figs © SINTEF]

> *Principles for avoiding thermal bridges*: (**a**) **Aim for an unbroken thermal insulation envelope** around the entire building; see Figs 6-8. This means that at building element junctions (e.g. roof/wall), their insulating layers should join without gaps or misalignment. If penetrations are unavoidable (e.g. balcony or wall/foundation), try to insert thermal breaks should that join to the insulation layers in the adjacent construction. Many documents [UK01, IE01, DE07] give a good coverage of the application of this principle. (**b**) **Keep façade geometry simple**. Further principles are given in [UK01].

> *Airtightness principles*: The above principles should ideally be presented together with the principles for achieving good airtightness, as these often have the same solution principles. See [UK01 page 13, IE01 page 15].

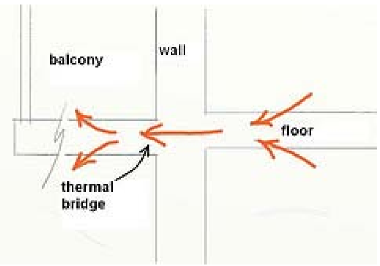

Fig.11 Simple illustration of balcony thermal bridge

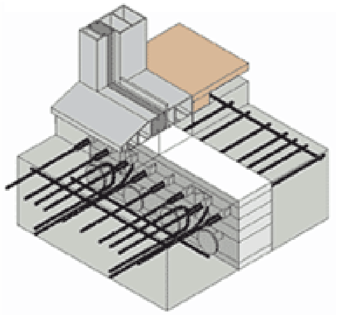

Fig.12 Detail of wall/floor junction, a typical point for thermal bridging

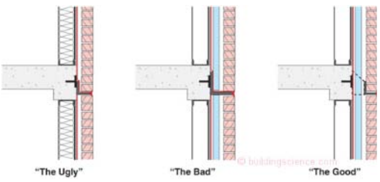

Fig.13. Examples of two poor and good details for metal lintels for supporting a cavity brick wall.

Fig.14 Foto of modern lintel bracket that permits unbroken layer of insulation to pass behind, before the brick wall facing is put up.

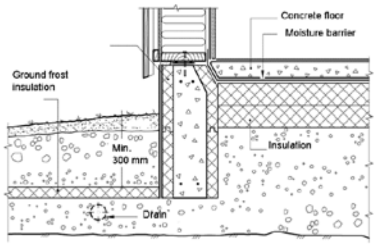

Fig.15 Detail avoiding thermal bridge and air leakage at the wall/slab-on-ground junction [© SINTEF]

(b) Illustrate the effects of thermal bridges

In order to encourage better insulation practice, the negative effects of thermal bridges should be well explained [*NO02*]:

> *Increased heat transfer* through thermal bridges. The consequence of heat loss through normal thermal bridges should be explicitly quantified (both in terms of energy and money). Also, it is important to explain the calculation of the heat loss, and the fact that the thermal bridge value (ψ) increases with increasing insulation thickness of the materials surrounding the thermal bridge. Thus the heat loss through thermal bridges will become increasingly important as member states tighten their insulation requirements. In warm climates, the effect of thermal bridges on cooling load should be highlighted.

> *Low surface temperatures.* This can lead to local condensation or eventually local blackening (aerosol condensation) on inside surfaces. Another consequence is reduced thermal comfort, such as cold floors or cold downdraught. Numerical evaluation is described in [*UK06*, & *EN ISO 10211*].

> *Low temperatures inside the construction.* This may lead to material stresses due to temperature variation, and possibly also interstitial condensation with resulting moisture damage.

(c) Well-illustrated examples of serious thermal bridges

It is important to present details from normal, local building practices that often incur serious thermal bridges. The UK & Irish Accredited Construction Details guides are a good example of this [*UK01* page 14, *IE01* page 18+]. Other useful guides are [*DE05*, *DE06*, *DE07*, *CA01*]. As a rule, the following building elements are critical:

> Balconies (e.g. Figs 11 & 12)

> Brick wall lintels (e.g. Figs 13 & 14)

> Wall/slab-on-ground junctions (e.g. Fig. 15)

> Window/wall junctions (e.g. Figs 5, 7, 8)

> Steel pillars, studs and sills integrated in the building elements

(d) Establish clearly-defined levels of 'good practice'

Each country should establish a quantitative level of good practice. This depends on local climate and insulation standards. In general:

> Introduce a recommended minimum thermal break dimension (mm) at critical details.

> Define minimum insulation thickness (mm) to avoid condensation.

> Define acceptable values of linear thermal bridges for various critical details, together with associated construction details.

> Other *qualitative* measures for good practice might include a Compliance Checklist; see for example page 8 of [*UK01*].

(e) Calculation methods

Explain how thermal bridges are to be calculated with reference to the national standards for area/heat transfer calculation and energy performance calculation. Ideally, show at least one example of a calculation for a whole building. Examples: [*NO08* page 48].

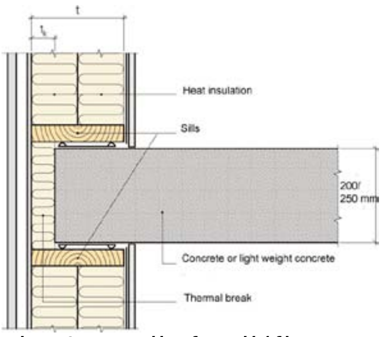

Fig.16 Detail of wall/floor junction, a typical point for thermal bridging

t	t_k	Floor material and –thickness (mm)					
		Concrete		Cellular concrete		Light weight concrete	
	mm	200	250	200	250	200	250
98	50	0,07	0,08	0,00	0,00	0,02	0,02
148	50	0,11	0,12	0,01	0,01	0,04	0,04
198	50	0,13	0,15	0,02	0,02	0,05	0,06
198	100	0,05	0,06	0,01	0,01	0,02	0,02
148 + 98	50	0,15	0,16	0,02	0,02	0,05	0,06
148 + 98	100	0,07	0,08	0,01	0,01	0,03	0,03
148 + 148	50	0,16	0,18	0,02	0,03	0,05	0,06
148 + 148	100	0,08	0,09	0,01	0,01	0,03	0,03
148 + 148	150	0,04	0,05	0,01	0,01	0,02	0,02

Table of thermal bridge values- for Fig.17, ψ [W/(mK)]

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3 > CONSTRUCTION DETAILS

(a) Collections of 'good practice' details

It is extremely useful to establish a collection of construction drawings that show how thermal bridges can be avoided. Some good examples are [*UK01*, *UK02*, *IE01*, *NL03*]. Examples of higher performance details are [*UK03*]. Examples for passive house standards are [*AT01*/*AT02*] and [*BE01*/*BE02*]. General guidelines are given here:

> Show rich details, not only showing thermal bridge measures, but also protection against driving rain, and airtightness features.

> Describe or illustrate the construction sequence for each detail. Ideally this should be in a form that can be accessible at the building site. For example, Norway has a pocket sized book of details intended for use on site [*NO09*].

> Take climate variations into account. Some countries have regions with different climates, and where different details may be needed.

> Establish a logical grouping/numbering system for the drawings. Many countries have such a system [notably *UK01* & *NL03*], some of which seem too complex.

> Ideally, detail annotations should be in a language-neutral form, such as numbers or letters, to allow easier adoption by other countries.

Countries can establish their own collections of accredited details by adopting good practice details from other countries with similar climate. Furthermore, the country should consider establishing a national procedure to enable new details to be quality controlled and adopted in the future. Un the UK, new details are assessed for compliance in accordance with the BRE IP1/06 [*UK07*] and BRE BR 497 [*UK08*] by a third party certification body. There should also be a feedback form for suggestions, e.g. [*IE01* last page].

(b) Calculated thermal bridge values

An atlas of thermal bridge values of the most common constructions should be established, giving values for the 'good practice' construction details described above, possibly supplemented with more details. See ASIEPI WP4 IP3. The calculation of heat loss through thermal bridges should follow the rules in EN ISO 10211. The atlas should include geometrical and non-repeating thermal bridges. The calculations should consider:

> Which thermal bridges can be neglected?

> Which thermal bridges can be calculated with the simpler method described in EN ISO 6946?

> The calculation of geometrical thermal bridges must be done according to national area definitions (use of external or internal measures).

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Link nr.	Country of origin	Language	Details? Guide? Method?	Cost? (2009)	PDF? WWW?	in ASIEPI archive?	Bibliographic reference	English description
International publications								
EU01	EU	English	Details, Guide	free	y	y	"Passive House Solutions". Report from EU EIE project Promtion of European Passive Houses. May 2006. (www.europeanpassivehouses.org)	Contains an overview of common details and best practice passive house details from different countries. See page 11 to 18. 50 pages
EN-ISO 10077-1	International	English & others	Method	€60,20	y	preview	EN ISO 10077-1 "Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General"	Calculation of the thermal transmittance of windows and pedestrian doors consisting of glazed and/or or opaque panels fitted in a frame, with and without shutters. Thermal bridge effects at the rebate or joint between the window or door frame and the rest of the building envelope are excluded from the calculation.
EN-ISO 10077-2	International	English & others	Method	€55,50	y	preview	EN ISO 10077-2 "Thermal performance of windows, doors and shutters Calculation of thermal transmittance – Part 2: Numerical method for frames"	Calculation of the thermal transmittance of frame profiles and of the linear thermal transmittance of their junction with glazings or opaque panels. Also valid for shutters and roller shutter boxes. Does not include effects 3D heat transfer such as pin point metallic connections, or thermal bridge between frame and the building structure.
EN-ISO 10211	International	English & others	Method	€62,30	y	preview	EN ISO 10211 "Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations"	Numerical calculation of heat flows through 2D & 3D thermal bridges, and risk of surface condensation.
EN 13187	International	English & others	Method	€60,00	y	preview	EN 13187 "Thermal performance of buildings - Qualitative detection of thermal irregularities in building envelopes - Infrared method"	Thermal performance of buildings - Qualitative detection of thermal irregularities in building envelopes - Infrared method (ISO 6781:1983 modified)
EN-ISO 13370	International	English & others	Method	€67,90	y	preview	EN ISO 13370 "Thermal performance of buildings - Heat transfer via the ground - Calculation methods"	Includes the influece of perimeter thermal bridges and breaks
EN-ISO 14683	International	English & others	Method	€55,50	y	preview	EN ISO 14683 "Thermal performance of windows, doors and shutters Calculation of thermal transmittance – Part 2: Numerical method for frames"	Simplified methods for determining heat flows through linear thermal bridges at junctions of building elements. Gives requirements to thermal bridge catalogues and manual calculation methods. Default values of given in Annex
Publications sorted by country								
AT01	Austria	English	Details	free	y	y	"IBO Passivhaus Bauteilkatalog – a catalogue of building elements specified for Passivhaus standard" by Waltjen, *10DBMC International Conference On Durability of Building Materials and Components,* Lyon, France. 17-20 April 2005	Presents the IBO Passivhaus Bauteilkatalog, a catalogue of construction details published in 2008
AT02	Austria	German & English	Guide, Details	€99.95	-	preview	"Passivhaus-Bauteilkatalog | Details for Passive Houses. 2008. Ökologisch bewertete Konstruktionen | A Catalogue of Ecologically Rated Constructions" IBO – Österreichisches Institut für Baubiologie und -ökologie (Hrsg.). Wien : Springer. ISBN 978-3-211-29763-6	Constructions & details conforming to passive house standards as well as up-to-date ecological evaluations. Gives information on the latest building materials. 310 illustrations. 347 pages
BE01	Belgium	English	Details	free	y	y	"Innovative solutions in passive house details" by Hilderson & Mlecnik. *PLEA 2008 – 25th Conference on Passive and Low Energy Architecture* , Dublin, 22nd to 24th October 2008	Describes Belgian research project Presti 5 'Details in the passive house standard', which produced details for both massive and wood construction of passive houses in the Belgian building tradition (www.bouwdetails.be)
BE02	Belgium	Flemmish	Details	free	y	y	www.bouwdetails.be	On-line interactive step-by-step 3D illustrations of passive house details, and downloadable 2D details with step-by-step construction
BE03	Belgium	Flemmish	Details, Guide	free	y	y	*WCB Contact nr.9* , March 2006. pp 10-12	Small news items with advice about thermal bridges in basement

Link nr.	Country of origin	Language	Details? Guide? Method?	Cost? (2009)	PDF? WWW?	in ASIEPI archive?	Bibliographic reference	English description
BE04	Belgium	Flemmish & French	Details	free	y	web link	"Koudebrug-IDEE" thermal bridge atlas. www.wtcb.be/go/koudebruggen (Flemmish) or www.cstc.be/go/ponts-thermiques (French)	An online atlas of 150 details with calculated thermal bridge coefficients, with a 5-page user manual
CA01	Canada	English	Guide	free	y	y	"Transitions - How to design facade interfaces" by Kazmierczak and Neeb. Journal of Building Enclosure Design (JBED), Summer 2007, pp 20-23	Short article explains the principle of continuous envelope layers for waterproofing, windproofing, insulation, vapour barrier, etc. Illustrated with examples of critical details.
CA02	Canada	English	Guide	free	y	y	"Thermal bridging in the building envelope" by O'Brien. In *The Construction Specifier* , Canada, October 2006	Short article on maximizing insulation effectiveness through careful design. Focus on cold climates
DE01	Germany	German	Method	€129,10	y	preview	DIN 4108 Beiblatt 2, 2006	2nd addendum of German Standard 4108. Thermal insulation and energy economy in buildings - Thermal bridges - Examples for planning and performance
DE02	Germany	German	Guide	free	y	y	"EnEV Energieeinsparverordnung". Arbeitsgemeinschaft Mauerziegel e.V., Bonn. 5th edition (2007), p. 31-33.	"EnEV" Energy Conservation Regulations. Regulation on energy conservation in buildings. Bonn : Publ. by Assoc. of brick manufacturers. 3 pages on thermal bridges.
DE03	Germany	English	Guide	free	y	y	"Design avoiding thermal bridges - preferable not only for Passive Houses". Passivhaus Institut (www.passiv.de)	Concise webpage on thermal bridges.
DE04	Germany	German	Guide	€15,30	-	preview	"Protokollband Nr. 14: Passivhaus-Fenster : Arbeitkreis kostengünstige Passivhäuser - Phase II", Passivhaus Institut	Technical guide on passive house standard windows, including thermal bridging around the frame, and consequences of mounting options.
DE05	Germany	German	Guide	€24,10	-	preview	"Protokollband Nr. 16: Wärmebrückenfreies Konstruieren : Arbeitkreis kostengünstige Passivhäuser - Phase II". Passivhaus Institut	Technical guide on thermal bridge free constructions. Explains the principles (esp. continuous insulation envelope), critical construction details, calculation of psi values, and examples of both lightweight and concrete constructions.
DE06	Germany	German	Guide	€24,60	-	preview	"Protokollband Nr. 24: Einsatz von Passivhaustechnologien bei der Altbau-Modernisierung : Arbeitskreises kostengünstige Passivhäuser ist erschienen - Phase III". Passivhaus Institut	General technical guide on technologies for energy-efficient building modernization (in particular multifamily housing). Thermal bridges are an improtant aspect of this, e.g. balconies.
DE07	Germany	German	Guide	€21,10	-	preview	"Protokollband Nr. 35: Wärmebrücken und Tragwerksplanung - die Grenzen des wärmebrückenfreien Konstruierens : Arbeitkreis kostengünstige Passivhäuser - Phase IV". Passivhaus Institut	Technical guide on structural design and thermal bridges, focusing on two critical areas: basements and balconies
DE08	Germany	German	Guide	?	-	-	"Niedrig-Energie-Häuser" by Erhorn, H. und Reiß, J. Fraunhofer-Institut für Bauphysik, Stuttgart (1994), p.3/5-3/21.	Report on low-energy housing
DE09	Germany	German	Guide	?	-	-	"Energie- und kostensparende Wohngebäude in Schopfheim". Wirtschaftsministerium Baden-Württemberg (1995), p. 49-85.	Brochure "*Energy-saving and cost-effective residential building in Schopfheim*". 300 low energy homes were built in Schopfheim. Construction cost increase of only 2 to 4% lead to a 30% reduction in heat loss. Publ.: Ministry of Economy of Baden Wuerttemberg. In collaboration with the Fraunhofer Institute for Building Physics, 86 pages
DE10	Germany	German	Guide	?	-	-	"Energetische Modernisierung von Wohngebäuden". Wirtschaftsministerium Baden-Württemberg (1999), p. 36-37	Brochure from federal state
DE11	Germany	German	Guide	free	y	y	"Weber 2001 Övolution - Fertighäuser im Wandel". Erhorn, H. et ali. Fraunhofer-Institut für Bauphysik (2001), p. 7-8.	Report on energy-efficient features of Weber houses. A couple of pages on thermal bridges. 35 pages
DE12	Germany	German	Guide	free	-	y	"Bauen für die Zukunft". Deutsche Energie Agentur (DENA) GmbH, Berlin (2004), p. 10-12.	"*Building for the Future*". Publ. by German energy agency

Link nr.	Country of origin	Language	Details? Guide? Method?	Cost? (2009)	PDF? WWW?	in ASIEPI archive?	Bibliographic reference	English description
DE13	Germany	German	Guide	?	y	y	"Bauliche Konzeptentwicklung für eine '3-Liter-Reihenhauszeile' im Rahmen von Modernisierungsmaßnahmen in Mannheim-Gartenstadt" by Reiß, J. and Erhorn, H. Fraunhofer-Institut für Bauphysik. Bauphysik 26 (2004), issue 6, p. 322-334.	Report on a rehabilitation project where the heating needs were drastically reduced by using high-quality thermal insulation. 40 pages
DE14	Germany	German	Guide	free	y	y	"Niedrigenergiehäuser - Wissenswerte Grundlagen zu Planung und Funktion". Ausgabe 07/2007, Überarbeitung 10/2007. Hessen, Ministerium für Wirtschaft, Verkehr und Landesentwicklung, Wiesbaden (Herausgeber); Institut Wohnen und Umwelt GmbH -IWU-, Darmstadt (Bearbeiter)	Concise guide on energy-efficient modern housing. Page 5 on thermal bridges. 20 pages
DE15	Germany	German	Guide	free	y	y	"Energetische Modernisierung von Wohngebäuden - Eine Chance für Veränderung" by Reuther & Weber. Darmstadt : Institut Wohnen und Umwelt, 2008. ISBN 978-3-941140-02-8	Guide to energy efficient retrofits of apartment buildings, with focus on insulation. Some stuff on thermal bridges
DE16	Germany	German	Details	?	y	-	Detail "Catalogue" made for individual building projects, compiled by Fraunhofer-Institut für Bauphysik	Various sources
DK01	Denmark	English	Method	€149	y	preview	Danish Standard DS 418 "Beregning af bygningers varmetab", with ammendments 1:2005 and 2:2008	Calculation of heat loss from buildings. Includes definition and calculation of thermal bridges, with some details. 3 documents
DK02	Denmark	English	Guide	free	y	y	"Thermal bridges in residential buildings in Denmark". OPET Work package RUE in prefabricated buildings. Brno, 2002	Brochure specifically on thermal bridges in danish residential buildings. Describes regulations, common types of thermal bridge; consequences of thermal bridges, and solutions
DK03	Denmark	Danish	Guide	€40,00	y	preview	SBi guide 189: "Smahuse". 2nd ed. 1999 with addendum 2002. ISBN 87-563-1005-6 & ISBN 87-563-1139-7	"*Small houses*". General guide on small housing, with addendum on thermal bridges. 142 pages and addedum 32 pages
DK04	Denmark	Danish	Guide	€70,00	y	preview	SBi guide 221: "Efterisolering af etageejendomme", 2008	"*Renovation of multi-storey buildings*". Brochure, not specific, but thermal bridges are included in several publictions from SBi
DK05	Denmark	Danish	Guide	free	y	y	"Forsøgshuse med nye typer klimaskærmskonstruktioner" by Rose & Tommerup. DTU rapport R-069, 2003. ISBN 87-7877-131-5	Experiments with new types envelopes. Brief description of 6 single family houses focusing on construction technology, economic optimization and calculations and measurements of heating energy.
DK06	Denmark	Danish	Details	free	y	y	"Kuldebroer ved vinduesfalselementer" by Rose. DTU report SR-9714, 1997	"*Thermal brides at window frames*", with some psi values
FI01	Finland	Finnish	Guide, Details	free	y	y	"Energiaa säästävä pientalo". Publ. by Timber Suppliers Assoc (www.puuinfo.fi), 2006	"*Energy-saving housing*". Design guide on wooden low-energy buildings, to reduce heating energy by 50%. Focuses on insulation. Includes details for thermal bridges & airtightness. 86 pages. The association (www.puuinfo.fi) also has other publictations with details.
FI02	Finland	Finnish	Details	free	y	y	eriste.paroconline.com	Structural details of various structural systems (Publ. by insulation manufacturer Paroc). The details do not give information on construction method or thermal properties
FI03	Finland	Finnish	Details	free	y	y	www.isover.fi/en/Constructual+Planning/Structure+Library	Some structural details (Publ. by insulation manufacturer Isover)
FR01	France	French	Guide, Details	€17,06	-	preview	"Les ponts thermiques dans le bâtiment - Guide practique", CSTB, 2006	"*Thermal Bridges in Building - A practical guide*". Thermal bridges: definition and calculation; The impacts of thermal bridges; Thermal bridge connections; Integrated thermal bridges; Thermal bridges and the building regulations; and a few pages of examples. 80 pages

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IE01	Ireland	English	Guide, Details	free	y 9 docs	y	Acceptable Construction Details (ACDs) for Technical Guidance Documents (TGD) Part L. 2008 (www.environ.ie/en/TGD/)	Details on thermal bridging and airtightness. Helps achieve Irish building regulations 2008 for dwellings. Has 2 sections: Section 1 is general theory of insulation continuity and airtightness in construction. Section 2 has details showing insulation and airtightness provisions. A Comment Sheet is also available
LT01	Lithuania	Lithuanian	Details	free	y	y	Dėl statybos techninio reglamento STR 2.05.01:2005 "Pastatų atitvarų šiluminė technika" patvirtinimo	Building regulation STR 2.05.01:2005 "*Thermal technique of the building envelope*", including Annex 7 "*Thermal transmittance coefficients of linear thermal bridges*"
NL01	The Netherlands	Dutch	Method	€57,60	-	preview	NEN 1068 "Thermische isolatie van gebouwen - rekenmethoden", geheel herziene 5e druk okt 2001	Official method
NL02	The Netherlands	Dutch	Details, Method	€57,60	-	preview	NPR 2068 "Thermische isolatie van gebouwen - Vereenvoudigde rekenmethoden", 1e druk jan. 2002	National practice guide with default psi values, 72 pages. Indicates hand calculaion method to determine the same quantities as in NEN 1068.
NL03	The Netherlands	Dutch	Details	€70 - €345. €1 per detail	y	preview	SBR-Referentiedetails (www.sbr.nl/referentiedetails)	Large collection of details together with thermal bridge psi values and other data. Available for different construction types, both residential and commercial buildings, and renovation, new, or passive house. Available in paper, online and electronic files (DWG, DXF) for import to CAD. Constantly updated with subscription.
NO01	Norway	Norwegian (English & Polish)	All	€950/yr	y	web link	SINTEF Building Research Design Guides (bks.byggforsk.no)	A series of 760 guides provides concrete solutions and advice on a wide range of specialist building issues, richly illustrated and with clear text. Updated monthly and available online (also CD-ROM and paper). 5 design sheets listed below are related to thermal bridges. 4 guides are in English and Polish
NO02	Norway	Norwegian	Guide	€15,60	y	preview	471.015 "Kuldebroer. Vurdering av konsekvenser og dokumentasjon av energibruk", SINTEF, 2008	Building design guide 471.015: "*Thermal bridges: Evaluation of consequences and documentation of energy use*"
NO03	Norway	Norwegian	Method	€15,60	y	preview	471.016 "Kuldebroer. Metoder for å bestemme kuldebroverdi", SINTEF, 1999	Building design guide 471.016: "*Methods of determining thermal bridge factors*"
NO04	Norway	Norwegian	Details	€15,60	y	preview	471.017 "Kuldebroer. Tabeller med kuldebroverdier", SINTEF, 2007	Building design guide 471.017: "*Tables of thermal bridge factors*"
NO05	Norway	Norwegian	Guide, Method	€15,60	y	preview	521.112 "Golv på grunnen med ringmur. Varmeisolering, frostsikring og beregning av varmetap", SINTEF, 2005	Building design guide 521.112: "*Slab on ground with ring foundation. Thermal insulation, frost protection and calculation of heat loss*"
NO06	Norway	Norwegian	Guide, Details	€15,60	y	preview	720.015 "Utbedring av kuldebroer", SINTEF, 1999	Building design guide 720.015: "*Improving thermal bridges*", for existing buildings
NO07	Norway	Norwegian	Guide	€44,50	-	web link	"Energieffektive løsninger i småhus" by Myhre & Dokka. Anvisning 40, 2004, Oslo : SINTEF Buildings & Infrastructure. ISBN: 82-536-0854-3	"*Energy-efficient solutions in small houses*". Pages 33-42 on thermal bridges. 76 pages
NO08	Norway	Norwegian	All	free	-	y	"Kuldebroer – Beregning, kuldebroverdier og innvirkning på energibruk" by Gustavsen et al., Report B21394, Oslo: SINTEF Buildings & Infrastructure, 2008. ISBN 978-82-536-1037–5	"*Thermal bridges – Calculation and influence on energy consumption*". Chapters: What is a thermal bridge, How avoid thermal bridges, Methods for determining thermal bridge factors, Numerical calculation of thermal bridges, Thermal bridge values, Heat loss and floor-area-specific thermal bridge value (NKV), Improving thermal bridges in existing buildings. Appendices: Steel frame thermal bridges method description, Data sheets with tables of thermal bridge values. 92 pages
NO09	Norway	Norwegian	Details	€40,00	n	n	"Trehus - figursamling for byggeplass", Oslo: SINTEF Buildings & Infrastructure, 2009. ISBN 978-82-536-1087-0	"*Wood construction houses – collection of drawings for use on building sites*". Pocket format book aimed at craftsmen on building sites. Contains a practical collection of recommended details.

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PL01	Poland	Polish	Method	?	?	web link	Publications of ITB, Warsaw 2003.	Guide on Polish Norms - EN related to energy characteristics of buildings, publications of ITB, Warsaw 2003.
PL02	Poland	Polish	Method	?	?	-	Association of Energy Auditors, Warsaw 2004.	Evaluation of energy quality of buildings; requirements - data - calculations. Educational material
RO01	Romnia	Romanian	Guide, Details	?	?	web link	For existing buildings: SC08-2002, NP060-2002. For new buildings: GP058-2000	Guides containing common construction details for typical buildings, with provisions and examples of correct and incorrect insulation. All guides/standards available electronically via www.matrixrom.ro
UK01	UK	English	Details, Guide	free	y. 6 pdfs	y	Accredicted Construction Details (ACDs) for Part L. 2007 (www.planningportal.gov.uk), for England & Wales	Building Regulations in England and Wales, catalogue of accredited details with regard to airtightness and thermal bridges. Replaces previous publication "Robust details" of 2001
UK02	UK	English	Details, Guide	free	y	y	Accredited Construction Details (Scotland). Scottish Building Standards Agency. (www.sbsa.gov.uk)	Building Regulations in Scotland, catalogue of accredited details with regard to airtightness and thermal bridges in low to medium rise buildings.
UK03	UK	English	Details, Guide	free	y 7 pdfs	y	Enhanced Construction Details (EDCs). Energy Saving Trust, UK (www.energysavingtrust.org.uk)	Voluntary enhanced best-practice designs from the Energy Saving Trust
UK04	UK	English	Details	€30	y	web link	"Robust details - Limiting thermal bridging and air leakage - robust construction details for dwellings and similar buildings", by DEFRA/DTLR. Publ. The Stationery Office. Reprint 2002. ISBN 0117536318	Known as the "Robust details" document. Supplied in ring binder with thumb-index. Supported the Part L of the 2001 Building regulations. **Has been outdated by the newer ACDs and ECDs [UK01 & UK03]**.
UK05	UK	English	Details	€72	y	web link	Robust Details (www.robustdetails.com), publ. by Robust Details Limited (RDL)	These details focus on sound insulation (Part E) but in principle should not have thermal bridge effects. **Not to be confused with the newer ACDs and ECDs [UK01 & UK03]**
UK06	UK	English	Details	€36,20	y	web link	"Thermal insulation: avoiding risks" by Stirling. BRE Report 262, 2002 edition, ISBN 1860815154	Recommendations of BRE on good design and construction practice associated with previous building regulations. Links technical risks, causes and solutions. Topics: insulation, energy, roofs, walls, windows, floors, pipes, thermal bridging, fire risks, condensation, ventilation. 80 pages. **May be partly outdated by the new regulations.**
UK07	UK	English	Details	€11,50	y	web link	"Assessing the effects of thermal bridging at junctions and around openings" by Ward. BRE Information paper IP1/06, 2006, 1-86081-904-4	Guidance on assessing the effects of thermal bridging at junctions and around openings in the facade. Gives a satisfactory estimate of heat transfer for the purposes of carrying out building regulations compliance calculations. 6 pages
UK08	UK	English	Details	€48,00	y	web link	"Conventions for calculating linear thermal transmittance and temperature factors " by Ward & sanders. BRE report 497, 2007, ISBN 978-1-86081-986-5	Gives the conventions for numerical modellers. For building regulation purposes, two key modelling outputs, temperature factor and linear thermal transmittance. These outputs enable designers to confirm the adequacy of particular junction details. 48 pages.
UK09	UK	English	Guide, Details	free	y	y	LowCarb4Real Design collection on thermal bridging	4 pages with concise information about thermal bridges with examples of real applications, from project *UrbanBuzz - Developing low carbon housing: Lessons from the field*
UK10	UK	English	Guide, Details	€20	?	preview	"Avoidance of thermal bridging in steel construction", Steel Constriction Institute (SCI), April 2008, ISBN 978-1-85942-182-6	Practical guidance for avoiding thermal bridge heat losses in steel framed buildings; supported by thermal modelling data. 36 pages
US01	USA	English	Guide	free	y	y	"Insight: A Bridge Too Far" by Lstiburek. Www.buildingscience.com	Short article on thermal bridges, steel studs, structural frames, relieving angles and balconies.