Thermal Bridges in the EPBD context

Heike Erhorn-Kluttig[1], Hans Erhorn[1], Marco Citterio[2], Manuela Cocco[2], Dirk van Orshoven[3] and Antoine Tilmans[3]

[1] *Fraunhofer Institute for Building Physics, Nobelstr. 12, 70569 Stuttgart, Germany*
[2] *Italian National Agency for New Technologies, Energy and Environment (ENEA), Via Anguillarese 301, 00060 S. Maria di Galeria (Rome), Italy*
[3] *Belgian Building Research Institute (BBRI), Avenue P. Holoffe 21, 1342 Limelette, Belgium*

ABSTRACT

Thermal bridges increase the building energy demand for heating and cooling. For well insulated envelopes and buildings with increased energy efficiency, the influence of thermal bridging on the energy consumption is of major importance. Here the ratio between the thermal bridging effect and the overall thermal losses increases compared to low or medium insulated buildings and it is possible that the effect of thermal bridges on the energy demand compensates or even overtakes, for instance, the energy gain provided by thermal solar collectors for domestic hot water. The impact of thermal bridging on the energy consumption is even more pronounced in the case of building retrofit, where solving thermal bridges often is an issue, especially where external insulation is not applicable because of architectural constraints or not effective because of the presence of a lot of balconies.

This paper is based on the work in a European project called ASIEPI (Assessment and Improvement of the EPBD Impact (for new buildings and building renovation), www.asiepi.eu). It presents three different issues in connection with thermal bridges:

1. National requirements and calculation procedures (detailed and simplified) in the Member States participating in ASIEPI. In order to facilitate a correct comparison amongst MS regulations, the overview is split per geographical and climatic area: Northern, Central and Southern Europe.
2. Impact of thermal bridges on the energy performance of buildings. Studies that analyse the influence of detailed calculations of thermal bridges in comparison of neglecting the influence, but also in comparison with default values for thermal bridges have been gathered for both summer and winter conditions.
3. Thermal bridge atlases and software to calculate thermal bridge effects. An overview and a categorisation of available atlases and software products have been made.

KEYWORDS

ASIEPI, thermal bridges, EPBD, requirements, energy performance, software

INTRODUCTION

The design and realisation of building components and components joints without or with as small as possible thermal bridges is important because of several physical aspects. Because of the lower thermal resistance of the thermal bridge the internal surface of the particular area of the building envelope has a lower temperature. This can result in moisture and even mould problems. Also the additional energy losses due to thermal bridges can become considerable, mainly for high performance buildings with low other transmission and ventilation losses. The losses can be even higher than, for example, the energy benefit provided by thermal solar collectors for domestic hot water. The public awareness of this fact is however very low.

Therefore, the national EP calculation procedures have to include the impact of thermal bridges. Moreover, best practice examples of advanced solutions or technologies should be widely presented, in order to promote the advantages of detailed planning of component joints in new and renovated buildings.

Thermal bridges can be distinguished into three main types:

1. Repeating thermal bridges within a construction element (structure or frame constructions). They are included in the overall U-value calculation of the element.
2. Thermal bridges at corners and junctions incl. windows and doors, wall/roof, wall/wall corners. The linear heat loss (psi-value) is multiplied by the length of the thermal bridge.
3. Isolated thermal bridges, like balconies penetrating insulation layers. The punctual heat loss has is multiplied by the number of thermal bridges. Many national energy performance calculation procedures do not request to include the isolated thermal bridges into the energy performance calculation.

In this paper thermal bridges of type 2 are mainly considered. An example of such a thermal bridge is presented in figure 1.

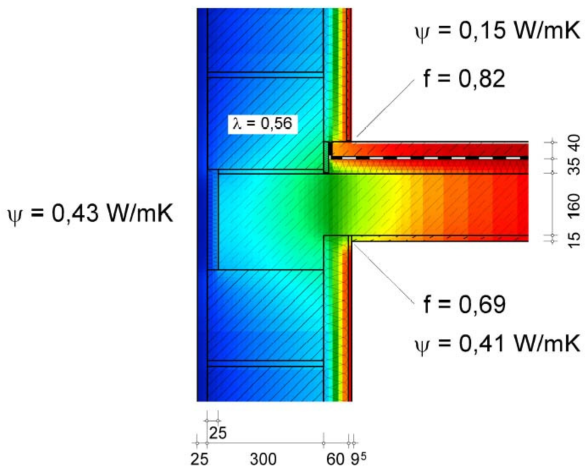

Figure 1: Example of a thermal bridge effect at a concrete ceiling embedded in the external wall. Calculation of the thermal bridge loss coefficient and the dimensionless temperature coefficient. The colours illustrate the temperature distribution within the construction. © Prof. Gerd Hauser, Fraunhofer Institute for Building Physics.

NATIONAL REQUIREMENTS AND CALCULATION PROCEDURES

Within the EU Intelligent Energy Europe project ASIEPI (Assessment and Improvement of the EPBD Impact (for new buildings and building renovation), www.asiepi.eu), an analysis [1] of the national approaches for the energy performance assessment of buildings as implementation of the Energy Performance of Buildings Directive was performed [2]. The project collected and compared in one of the working areas the requirements and the calculation procedures (detailed and simplified) in the EU Member States regulations.

At the time of the study (spring 2008) almost all Member States' building energy performance regulations deal with thermal bridges, but the approaches and especially, minimum requirements considerably differ from each other. In order to facilitate the overview the countries were split into geographical and climatic areas:

Northern (Denmark, Norway and Finland), Central (Belgium, the Netherlands, Germany, France, Poland and the Czech Republic) and Southern Europe (Greece, Spain, Portugal and Italy). Figure 2 shows that all countries in Northern and Central Europe are dealing with the problem of thermal bridges as far as new constructions are concerned. For the countries included in Southern Europe this was not the case, simply because Greece was still working on setting up the regulation. The existing Greek regulation at that time did not consider the influence of thermal bridges in buildings at all. This has however changed in the meantime.

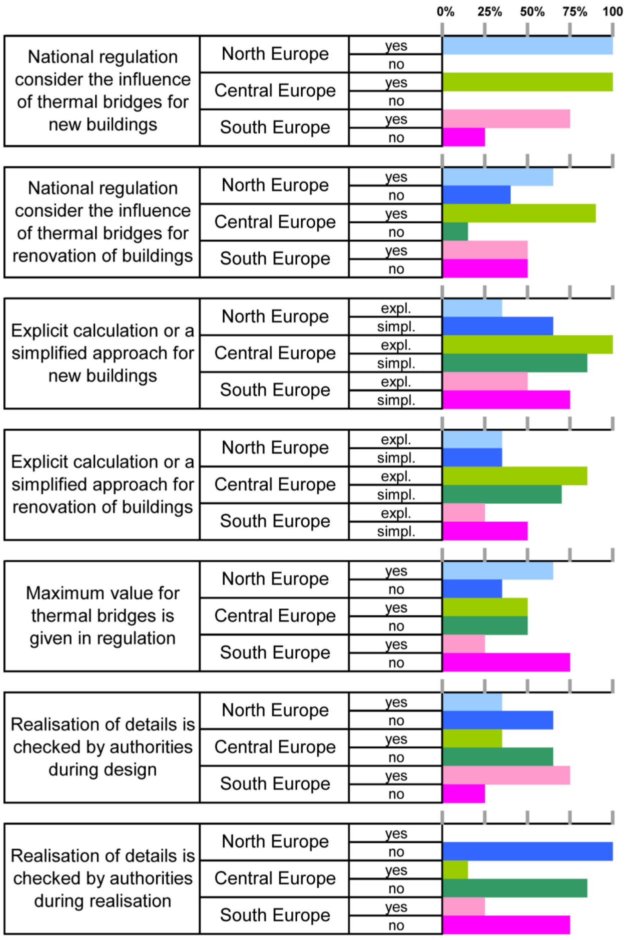

Figure 2: Overview of approaches concerning how thermal bridges are covered in national regulations.

Not all countries require covering the thermal bridge issue in energy performance calculations for existing buildings. Special attention has been given to collecting information on simplified approaches. They are used in all three climatic regions, with Northern and Southern European countries using more simplified approaches than detailed calculations and Central Europe vice versa. All Central European countries at least offer the possibility to make a detailed thermal bridge assessment in the energy performance calculation. Nearly all of them allow a simplified approach, too.

There are many methods to deal with the maximum value for thermal bridges in regulations: In Germany the dimensionless temperature factor f_{Rsi} is used, in Denmark and Czech Republic a ψ_{max} value is set depending on the type of joint, in France the ψ_{max} depends on the type of building. In addition, compliance and control issue were analysed. The realisation of details is sometimes checked during the design phase, especially in Southern European States. A check during the realisation phase is performed much more seldom, even though some countries or regions within countries foresee such a procedure.

IMPACT OF THERMAL BRIDGES ON THE ENERGY PERFORMANCE OF BUILDINGS

In the same project existing national studies on the impact of thermal bridges on the energy performance of buildings have been gathered and analysed [3]. Most of the available studies deal with the winter performance, only one study presented results concerning the impact in summer. Many studies compared the existing national default values for thermal bridges with detailed thermal bridge calculations, some of them with improved joints. Others analysed the total impact of thermal bridges on the energy performance comparing them to not including the influence at all as if no thermal bridges would occur in the buildings. Also the amount of analysed joints, the building geometry, the climate etc. vary between the studies. For both summer and winter impact one study is summarised in the following sections.

German study: Demonstration project 3-liter-houses Celle – Thermal bridge influence on the energy performance of the Ziegel-Aktiv-Haus [4]

In this demonstration project concepts for high performance houses have been developed and some of the concepts have been built, see figure 3. The aim was to achieve a primary energy demand of less than 34 kWh/m²a which can be recalculated to less than 3 liter oil per m² and year for space heating, ventilation and auxiliary energy. The concepts included different technologies and strategies, one of them being the reduction of energy losses due to thermal bridges. To this end, not only have advanced building joints been developed, but also a study on the comparison of the default values for thermal bridges that are used in the German energy performance code with the explicitly calculated values has been carried out. The German standard DIN V 4108-6 foresees default values for standard joints (ΔU=0.10 W/m²K) and for state of the art joints (ΔU=0.05 W/m²K) according to a leaflet with example joints.

Figure 3: Photo of the double house used for the German study on the impact of thermal bridges on the energy performance of buildings.

The double house consists of an advanced brick construction with low thermal conductivity of the bricks, highly insulated roof and basement slabs and triple glazed low-E-coated windows. The heating system of each unit is a gas condensing boiler combined with solar collectors feeding into the heat storage and ventilation by window opening in one, and a mechanical ventilation system with heat recovery in the other. There have been 16 linear joints analysed and improved starting from the external wall corners, window and door frame connections, roof-wall joints, dormer constructions, to connections between wall and slab. The results of the study are presented in table 1.

Table 1: Results of the German study on the impact of thermal bridges on the heating energy.

Savings of Ziegel-Aktiv-Haus compared to	Standard	State of the Art
ΔU [W/m²K]	-0.081	-0.031
Energy need for heating [kWh/m²a]	-11.4	-4.4
Primary energy for heating [kWh/m²a]	-9.9 / -12.6*	-3.8 / -4.8*

* two different heating systems in the double house units.

Compared to the standard values for joints the net energy demand for heating can be reduced by 11.4 kWh/m²a if all joints are well designed and explicitly calculated. Compared to state of the art joints 4.4 kWh/m²a can be saved. For the building systems used in the two units of the double house, the primary energy for heating can be reduced by 9.9 kWh/m²a respectively 12.6 kWh/m²a referred to standard constructions and still about 4 to 5 kWh/m²a referred to state of the art constructions. As 34 kWh/m²a primary energy for heating and ventilation is the limit for such a high performance building, a reduction of 5 kWh/m²a (=15 %) is an important part of the energy concept. The necessary reduction of the wall U-value compared to state of the art to compensate for not improved joints would be 0.1 W/m²K (with a 90 m² wall). Thermal bridges (and airtightness) have the same influence as solar thermal hot water generation if compared with standard joints (>10 kWh/m²a primary energy reduction).

Greek study: The impact of thermal bridges on the energy demand of buildings with double brick wall constructions [5]

This study dealt analysed representative configurations of thermal insulation at external walls in order to investigate the impact of the thermal bridges on the energy consumption in both summer and winter conditions. A three-storey apartment building equipped with heating and cooling systems was calculated with a dynamic simulation program under the climate of Thessaloniki. While the study assesses 4 different insulation scenarios from typical application to external insulation it also calculates the (total) impact of thermal bridges on the heating and cooling demand. For this paper the results of the thermal insulation scenario according to the minimum requirements for the coldest zone in Greece (5 cm insulation thickness) are summarised in table 2.

Table 2: Results of the Greek study on the impact of thermal bridges on the heating and cooling energy.

Characteristic value	Unit	Excluding thermal bridges	Including thermal bridges
Specific annual energy use for heating	kWh/m²a	71	92
Maximum heating load	kW	24.8	30.4
Specific annual energy use for cooling	kWh/m²a	30	31
Maximum cooling load	kW	15.4	17

The impact of the thermal bridges on the annual energy need for heating is 30 % or 21 kWh/m²a. The specific energy need for cooling difference is much lower with

1 kWh/m²a or 3 %. On the other hand, the calculations show that also the summer influence of thermal bridges shouldn't be neglected as the difference of the maximum cooling load is more than 10 %. It can be assumed that if the climate region would have been warmer, the impact on the cooling load and cooling energy need would have been higher.

SOFTWARE AND ATLASES FOR EVALUATING THERMAL BRIDGES

Specific tools are needed to determine the linear or punctual thermal values. There are two kinds of tools: numerical calculation software and thermal bridge atlases. Numerical calculation should be carried out using validated software and following rules that are usually given in a standard, which in the framework of energy performance of buildings regulations is usually the European/International standard EN ISO 10211. The standard defines modelling rules for thermal bridges and test cases for software validation. IEE ASIEPI has listed in an information paper [6] the software tools used in different EU Member States and specified them into capabilities of the software (heat transfer only / heat, air and moisture transfer / multiphysics), 2-dimensional or 3-dimensional, steady-state or transient, free form or rectangular model, free or commercial and validated according to EN ISO 10211 or not. At the time of the study some software programs did not have documented validation.

For standard details it might be easier and faster to use an atlas of thermal bridge details. Also here the project has collected the documents that are used in EU Member States. While in most countries those atlases are reported to be in common circulation, they don't appear to be widely used in Greece, Italy, the Netherlands and Finland. There are different kinds of thermal bridge atlas. Many exist as stand-alone documents, originally developed independently of the EPBD-regulation. Others have been developed specifically for the EPBD-regulation. Such atlases can be of the ordinary type, i.e. a simple collection of building details with corresponding values of interest (e.g. linear thermal transmittance, temperature factor,...). Or it can be a set of details that are considered as good-practice details in the framework of the EPBD-regulations. Finally, values of linear thermal transmittances are also given in the European/International standard EN ISO 14683.

REFERENCES

[1] Citterio, M. et al (2008). Thermal bridges in the EPBD context: overview on Member States approaches in regulations. Information Paper P64 of the EPBD Buildings Platform.

[2] EPBD (2002). Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. Official Journal of the European Communities, 04.01.2003.

[3] Erhorn-Kluttig, H. and Erhorn, H. (2009). Impact of thermal bridges on the energy performance of buildings. Information Paper P148 of the EPBD Buildings Platform.

[4] Erhorn, H. et al (2002). Demonstrationsvorhaben 3-Liter-Häuser Celle. Proceedings Ziegel-Forum Professoren Tagung, Lindau, Germany, 14.07.2002.

[5] Theodosiou, T.G. and Papadopoulous, A.M. (2008). The impact of thermal bridges on the energy demand of buildings with double brick wall constructions. Energy and Buildings 2008:40.2083-2089,

[6] Tilmans, A. and van Orshoven, D. (2009). Software and atlases for evaluating thermal bridges. Information Paper of the EPBD Buildings Platform.