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Calculation and compliance procedures of thermal bridges in energy calculations in various European countries

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Abstract

EPBD directive 2002 and its recast 2010 have led to significant efforts in Member States to improve the energy performance of buildings. Important aspect of this goal is the compliance of building energy performance assessment which needs developed procedures in order to be able to achieve stringent energy targets in practice. Transmission characteristics have a significant role in energy efficient buildings. QUALICHeCK project conducted a review of thermal bridges in energy calculation and compliance procedures in nine European countries (Austria, Belgium, Cyprus, Estonia, France, Greece, Romania, Spain, Sweden). Results showed that there are four main types of methods to take thermal bridges into account in transmission heat loss calculation: the detailed calculation based on linear thermal transmittance values, simple basic rules, default transmittance values, and mean U-values. Regarding the compliance, review showed that often there are no specific thermal bridge related compliance procedures. General conclusion of this study was that compliance frameworks needs to be extended in order to be able to assess as built energy performance. It is common approach in many countries that control mechanisms stop with building permit phase.

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Keywords: Thermal bridges; energy calculations; compliance assessment

1. Introduction

Influence of thermal bridges to building energy need is becoming more important whereas the goal is to achieve nearly zero energy buildings. Previous studies have shown that the impact of thermal bridges on the heating energy need of the building can be as high as 30% [1]. The impact of thermal bridges on the energy consumption can be even more significant in the case of building retrofit. Study conducted in Estonia [2] showed that in retrofitted apartment...
building, heat loss through window-wall junction was higher (19 MWh/a) than through insulated opaque walls (14 MWh/a). Study conducted in Belgium [3] concluded that there was an average difference of 7 kWh/(m² a) between the net energy need reduction from the original to the refurbished with non-refurbished joints on the one side, and the net energy need reduction from the original to the refurbished with refurbished joints on the other side.

Energy Performance of Building Directive [4] Annex I states that the methodology for calculating the energy performance of buildings must take into consideration thermal bridges. A variety of regulations and thermal bridges calculation practices are used in Member States. QUALICHeCK project studied thermal bridges calculation rules and practices in 9 European countries.

2. Thermal bridges calculation rules in energy calculations

Thermal bridges calculation rules are addressed in the building codes of all studied countries. Detailed thermal bridges calculations are allowed in all countries but there is also an alternative way. Results showed that there are five different types of alternative approaches for thermal bridges calculations in studied building codes, see Table 1.

<table>
<thead>
<tr>
<th>Thermal bridges calculations</th>
<th>Description</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation with energy calculation software</td>
<td>Thermal bridges values are calculated using a mandatory software for energy calculations</td>
<td>France</td>
</tr>
<tr>
<td>Tabulated values in energy calculation software</td>
<td>Values for thermal bridges in energy calculation software will be computed without the need of user input</td>
<td>Austria, Cyprus, Greece, Spain</td>
</tr>
<tr>
<td>Basic verification rules</td>
<td>Simple rules which, when followed, do not require calculation of linear thermal transmittance values</td>
<td>Belgium</td>
</tr>
<tr>
<td>Tabulated values in legislation</td>
<td>In the absence of more specific data, it is allowed to use tabulated values given in legislation</td>
<td>Estonia</td>
</tr>
<tr>
<td>Mean U-values</td>
<td>Mean U-values for the building envelope components includes linear and point thermal bridges</td>
<td>Romania, Sweden</td>
</tr>
</tbody>
</table>

2.1. Thermal bridges values can be calculated with energy calculation software (France)

The thermal bridges values are calculated using a RT 2012 [5] software and the respect of the aforementioned requirements is mentioned in the thermal study report, as seen in Figure 1.

![Fig. 1. Excerpt of a typical thermal study report, respect of thermal bridge requirements is mandatory (shown in red circle).](image-url)
Thermal bridges are considered in RT 2012 and must be calculated for all new constructions. Thermal regulatory calculations must be performed using standardized formulas which are incorporated in an approved software. In fact overall linear thermal transmission ratio (thermal bridges) of the whole building must be less than 0.28 W/(m² floor K). Are considered for this calculation linear thermal bridges due to the binding of at least two walls, of which at least one is in contact with the outside of the building. This includes thermal bridges of the periphery of the lower and intermediate floors, thermal bridges of the periphery of the roof and other thermal bridges such as the links of the perimeter of windows or those of rolling shutter casing. Furthermore, thermal bridges between intermediate floors and facades must be less than 0.6 W/(m K).

2.2. Thermal bridges values are given in energy calculation software (Austria)

In the Austrian EPC calculation, two-dimensional thermal bridges are considered in the design EPC calculation with the use of a conductance surcharge value $L_\psi$, which is included in the calculation of the transmission conductance value $LT$ according to an equation described in Austrian Standard ÖNORM B 8110-6:2010, p. 9.

To determine conductance surcharge values for thermal bridges the following methods are permitted according to Austrian Standard ÖNORM B 8110-6 (p. 13) [6]:

- Default EPC calculation with general formula and predefined $\psi$-values from Table 1 in Austrian Standard ÖNORM B 8110-6:2010 [6]
- Reference $\psi$-values from thermal bridge catalogues or in line with Austrian Standard ÖNORM EN ISO 14683:2007 [7]
- Detailed calculation according to Austrian Standard ÖNORM EN ISO 10211:2007 [8]

If a standard calculation with the general formula is conducted by the use of EPC software, conductance surcharge values for thermal bridges will be computed autonomously without the need of user input. If detailed calculation method is selected, thermal bridges will have to be entered individually with their linear thermal transmittance value and associated effective length. Thus, depending on the complexity of the project, EPC experts or specialised building physicists do the calculations.

There are no minimum requirements regarding thermal bridges. However, the OIB-RL6 contains $U$-value minimum requirements regarding elements of the building envelope, such as outer and inner walls, different types of ceilings, and different types of windows.

2.3. Thermal bridges values are based on basic rules (Belgium)

To incorporate thermal bridge requirements in the EPB-regulation, a pragmatic approach has been developed in a collaboration between the different regional governments and research institutes KULeuven, UGent and BBRI [9]. The methodology, introduced in the EPB-legislation in 2011, foresees three main options to take thermal bridges into account: the detailed calculation method based on linear thermal transmittance values, a pragmatic method based on simple basic rules and default transmittance values, and a penalisation method when no attention is paid to thermal bridges. Mainly the pragmatic approach was well appreciated and taken up by the building industry, since it is based on simple rules which, when followed, do not require any calculation of linear thermal transmittance values at all. Essentially, the basic rules aim to guarantee a continuous insulation layer within the building envelope. The performance-based rules are defined in such a way that the requirements are relative to the insulation level of the building. Furthermore, their simplicity allows designers, contractors and EPB-reporters to control, mainly in a visual manner, whether details fulfils the requirements to be an EPB-accepted node. This way the pragmatic approach not only effectively accounts for the extra losses due to thermal bridges in the building envelope, it also increases the awareness of good thermal detailing in the building industry.

Apart from fulfilling one of the three basic rules a thermal bridge is also considered to be EPB-accepted if its thermal transmittance is smaller than a limit value (see Figure 2). The limit value is depending on the geometry of the construction node. This allows for instance building industry to provide specific thermal bridge atlases that can be applied by designers without any further calculations. Several major building manufacturing companies have
developed product documentation and reporting tools based on the EPB-methodology. When thermal transmittance values are calculated this should be done according to the specifications for validated numerical calculations included in the legislation.

**Fig. 2. Possibilities for the assessment of EPB-accepted nodes**

2.4. **Thermal bridges tabulated values given in legislation can be used (Estonia)**

Thermal bridges are taken into account in energy calculations with linear thermal transmittance values. There are no specific requirements that need to be fulfilled for the linear thermal transmittance values. Linear thermal transmittances of thermal bridges are calculated using the preliminary building design data and are reported in building design documents and/or energy calculations input data sheet. It is advisable to calculate the linear thermal transmittance of thermal bridges with detailed or simplified calculations in accordance to standards (ISO 10211, EN ISO 10077, EN ISO 14683, ISO 15099), or use manufacturer's data. In the absence of more specific data, it is allowed to use tabulated values given in legislation [10]. Tabulated values given in legislation are very conservative (see Table 2) and intention was to motivate designers to calculate linear thermal transmittance values. In practice, there are complaints that tabulated values are too high, but using the values given in legislation has become main approach.

<table>
<thead>
<tr>
<th>Linear thermal transmittance, W/(m K)</th>
<th>New buildings</th>
<th>Major renovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>External wall-external wall</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>External wall-internal wall</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>External wall-internal ceiling</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>External wall-roof</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>External wall-ground floor</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>External wall-window (inside insulation layer)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>External wall-window (without insulation layer)</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>External wall-balcony</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

2.5. **Thermal bridges values can be taken into account in mean U-values (Romania)**

For calculation of transmission losses, the mean U-values are calculated for building components and for the whole building envelope. This includes linear and point thermal bridges calculation. Romanian regulations [11] contain prescriptive element-based criteria for thermal performances of building components, similar with the provisions of EN 13789, as well as a global heat transfer coefficient of the heated volume, G-value (W/m² K), as an overall minimum
requirement, depending on the number of the building floors and the external area per volume ratio (A/V). The design documentation that includes the G-value calculation is usually the building permit documentation. The thermal calculations are usually done by the designer (engineer or architect) and should be checked by an accredited expert (for quality in constructions, requirement F – thermal insulation of buildings). In practice the energy auditor for buildings is also performing the thermal calculations for the building permit.

For both design documentation and for the building Energy Performance Certificate, psi values for thermal bridges must be calculated or selected from already calculated tables (e.g. Catalogue of thermal bridges). Only for preliminary design the use of simplified calculation of thermal bridges effect is allowed based on correction factors.

3. Compliance assessment

Compliance and verification processes are often missing. In most of the studied countries, there are no specific procedure for compliance and verification process (except in Belgium, sample control in France and U-values based control in Romania).

In Belgium, the energy performance of new and renovated buildings is assessed at the moment of completion of the works by an EPB-assessor, who collects the as-built information, creates the necessary input in the EPB-software, and evaluates whether the building meets the requirements. The EPB-declarations with the results are uploaded to a database, managed by the regional authorities. In case requirements are not met, the builder is charged with a fine proportional to the size and severity of the error. Concerning thermal bridges, the EPB-assessor selects one of the three methods to take thermal bridges into account and collects the necessary information to make the assessment (architectural details, product data). There are no specific thermal bridge related compliance procedures. However, the approach has increased awareness of good thermal detailing in building industry and design. The effect is visible on construction sites: the use of specific solutions to avoid thermal bridges has increased (thermal breaks, continuity of thermal insulation). The approach has also stimulated the development of more specific guidelines and tools by building industry.

In France, at the end of construction, a Declaration Attesting Completion and Compliance of Works must be delivered. This declaration certifies that the undertaken work is compliant with the Thermal Regulation RT2012, including thermal bridges. After the deliverance of this certificate no further control or inspection is required by the current French legislation. However, controls of construction regulations are performed annually on a sample of new buildings. They aim to raise stakeholder’s awareness concerning the respect of construction regulations, improve the quality of buildings and the understanding of legislation. Each year a sample of new buildings is therefore controlled, based partly on a random draw and partly on local control policy. In case of non-conformities, an official report is addressed to a public prosecutor who will decide the legal consequences. This may include closure of the case, closure of the case upon regularization of the situation, or prosecution specifying the required sanction (fines, demolition ...).

In Romania, the current regulations do not provide limitations for thermal bridges coefficients, but for new buildings the U-values (including the effect of thermal bridges) are limited for each type of building envelope component as maximum average values. The compliance is ensured by the building permit documentation which contains the notice (approval) from the State Inspectorate in Constructions (not issued without the U-values and G-value compliance report).

Absence of compliance and verification processes is also connected with the energy calculations delivery time. Energy calculations are often presented with building permit [12], although it is clear that the energy calculations results made available to the end-user should be based on as-built characteristics. This means that often there are no control mechanism and related practices how to take into account changes in final design and production information as well as design changes during construction.

4. Conclusions

Thermal bridges calculation rules are addressed in the building codes of all studied countries. Compared to the other aspects such as strict requirements for the thermal transmittance of the building envelope, the energy losses through thermal bridges are often not sufficiently taken into account. Main solution in practice seems to be some kind of simplified approach where calculations of thermal bridges are not required and in many cases tabulated or default
values in energy calculation software are used. In highly insulated buildings, where the impact of thermal bridges on the heating energy need is significant, a correct thermal bridge accounting is evidently important and more attention is needed either to implement reliable simplified method or general calculation method. The calculation of linear thermal transmittance of thermal bridges is not more complicated procedure than dynamic energy simulations, which is required in many countries. Therefore, calculations of thermal bridges should be a defined task in the design process. Correct values of linear thermal transmittance of thermal bridges are also helpful for the buildings owners as this could reduce construction costs. Countries with national default values for thermal bridges have mostly set those values in order to be on the “safe side” meaning that they result in higher impact to buildings energy need than if the joints are analysed in detail calculations [1].

Compliance and verification processes are often missing. In most of the studied countries, there are no specific procedure for compliance and verification process (except in Belgium, sample control in France and U-values based control in Romania). How tabulated or default values correspond to the real values of as built solutions in construction site, is unknown. Another issue is that control mechanism often stops at building permit phase. This means that possible changes in construction phase are not taken into account in energy calculations results given to the end-user.

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