A pragmatic approach to incorporate the effect of thermal bridging within the EPBD-regulation

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SUMMARY:
Even for low energy and passive houses, the influence of thermal bridges occurring in the building envelope can be of major importance for the global energy performance of the building. As a result, the impact of thermal bridges is taken into account in the energy performance regulation of most European countries. The most accurate method is calculating the linear or point heat transmission coefficient of each thermal bridge and multiply it with the respective length or number. To avoid the time consuming numerical assessment of each detail of the building envelope, several European countries also allow a simplified approach based on thermal bridge atlases or default values. In most cases, these alternatives are only limited applicable and still require the intensive task of calculating the length and number of all thermal bridges. To avoid this, while at the same time still promoting good thermal detailing, a pragmatic approach has been developed in the framework of the Belgian energy performance regulation. In this approach, which is in addition to a detailed analysis, no calculation is necessary – even no lengths or numbers of thermal bridges have to be calculated – if all details are in agreement with some basic rules. The rules are written in such a way that the acceptable solutions of junctions are related to the overall thermal performance of the building. This paper presents the developed methodology and shows the advantages compared to the standard way of dealing with thermal bridging. Not only does the methodology increase the awareness of thermal bridging amongst architects and engineers; the developed basic rules are also easy to apply and can be checked during design and realization phase of the building.

1. Introduction

As a result of the Energy Performance of Buildings Directive (EPBD) all European member states implemented or strengthened their building energy performance legislation. This led to an increase of the thermal insulation quality and energy efficiency of both newly erected and renovated buildings. Though thermal bridges are not explicitly mentioned in the EPBD, previous studies (e.g. Erhorn et al., 2010; Theodosiou and Papadopoulous, 2008) showed that the influence of thermal bridges occurring in the building envelope can be of major importance for the global energy performance of the buildings. Since several thermal bridges such as wall-wall, wall-floor and wall-roof corners, junctions at windows and doors, ... cannot be avoided, the additional losses due to thermal bridges tend to become more and more substantial, certainly for low-energy and passive buildings.

Nowadays, the building energy performance regulation of almost all European member states incorporate requirements on thermal bridges. But since each member state is free to define its own requirements and calculation methods, several approaches exist. The most exact way to account for the additional losses, is by means of a detailed numerical analysis. The last decades several numerical codes for the simulation of building components became (commercially) available. An overview specific of thermal bridge software can be found in the Final Report of the European ASIEPI-project (Erhorn e.a., 2010). According to standards as EN ISO 10211, complex thermal bridges are in this way characterised by a linear (W/m.K) or point (W/K) heat transmission coefficient. For almost all member states, the explicit calculation of thermal bridges is an accepted option to take the extra losses into account. Although the most precise, the time-consuming character of this method forms an important disadvantage. To overcome this, several countries also allow a simplified approach. The most simplified method is by adding a correction factor ΔU to the U-value of the different envelope areas to take thermal bridging into account (e.g. The Netherlands, Germany, Poland, Spain). More precise, but often still simplified, is the use of tabulated values for specific details or the application of a thermal bridge atlas (e.g. Denmark, France, Germany, Spain).

Within the Belgian context, a different approach is applied. Taking good thermal detailing as starting point, basic rules have been developed which – when applied – assure limited losses through the thermal bridges. The basic rules increase the awareness of thermal bridging amongst contractors, architects and engineers and are at the same time easy to apply, don't request any calculation and can easily be checked during design and construction phase of the building. Apart from this pragmatic approach, the legislation still allows two other options: a detailed numerical analysis or a fixed penalty as compensation if no attention is paid to thermal bridges.

The current paper describes the developed Belgian methodology. First a short introduction on the implementation of thermal bridges in the Belgium EPBD-regulation is given and the three options are described. Then the simplified pragmatic approach with the basic rules ensuring the continuity of the thermal break is presented.

2. Incorporating thermal bridges in the Belgium EPBD-regulation

Though energy, and hence the implementation of the EPBD-regulation is a regional matter in Belgium, the three Belgian regions (the Flanders, Walloon and Brussels-Capital region) decided to apply all the same methodology to take thermal bridges into account. The methodology has been developed by a working group with partners from different universities and research institutes, in cooperation with the different regional governments.

As in several European countries, a distinction is made between the different types of thermal bridges typically occurring in building envelopes: repeating thermal bridges within envelope components (e.g. wooden studs in a light weight building wall), thermal bridges at corners and junctions (e.g. wall-wall corner, window-wall connection,...) and local penetrations of the insulation layer of a building component (e.g. load bearing connections for balconies,...). The first type of thermal bridges was already accounted for in the EPBD-regulation, since these extra losses have to be incorporated in the overall U-value of the building element. For the other two types; thermal bridges at corners and junctions and local penetrations, the idea was originally to develop a Belgian thermal bridge atlas in correspondence with foreign examples. Due to the fragmented building market in Belgium, this, however, showed to be an almost impossible task. Furthermore, the fear existed that the fact that a thermal bridge atlas still requires the intensive task of calculating the length and number of all thermal bridges, would result in reluctant building market. To avoid this, while at the same time still promoting good thermal detailing, a pragmatic approach has been developed by the working group. A proposal for a consistent methodology making use of three main options (a traditional calculation method, a pragmatic approach based on basic rules and a compensating method) has been finalised in 2010 by the working group. The three regions agreed on this methodology and each of them will implement it within the EPBD-regulation of their own territory in the near future.

3. Three options to take thermal bridges into account

As stated before, the effect of repetitive thermal bridges within building envelope parts has to be incorporated in the U-value of the component. The developed methodology only concerns the thermal bridges at corners and junctions and the isolated penetrations of the insulation layer of building components. To take these thermal bridges into account, three options are foreseen in the new legislation as illustrated in Figure 1.

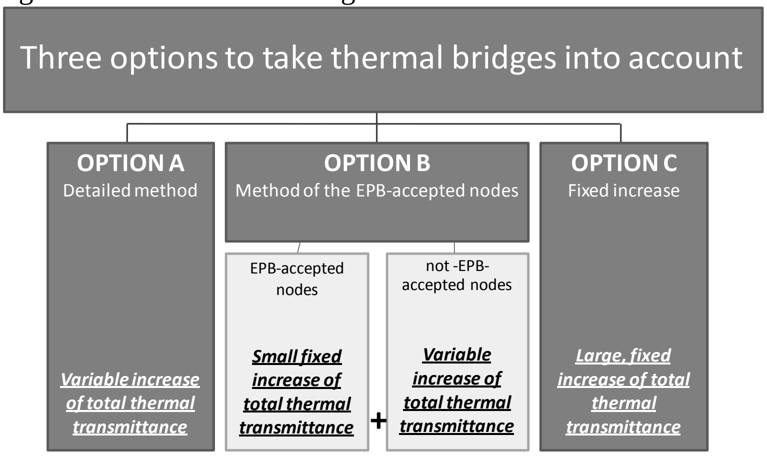


FIG 1. Incorporating thermal bridges in the Belgian EPB-regulation: overview of the three options to take thermal bridges into account.

The first option, option A, corresponds to the standard detailed approach taking into account all extra losses by multiplying for each thermal bridge the length/number with the linear/point thermal transmittance. This implies time-consuming numerical calculations or as an alternative the use of (rather negative) default values. Option B corresponds to the pragmatic approach and is called the method of the EPB-accepted nodes (note that because of the negative connotation, in the legislation the word 'thermal bridge' has been replaced by the more neutral word 'junction' or 'node'). In this option, all thermal bridges are classified into two categories: EPB-accepted thermal bridges satisfying certain continuity criteria of the insulation layer (see §4) and other thermal bridges. In a previous study the impact of the thermal bridges on the overall heat transmission was investigated for some typical Belgian buildings (Janssens et al., 2007). It was found that with a good thermal performance of the detailing, the impact of the thermal bridges on the overall thermal transmittance (W/K) was very similar for all type of buildings (see Figure 2). Therefore, a small fixed increase of the overall thermal transmittance is associated with the EPB-accepted nodes. Based on simulations as presented in Figure 2, the value of the fixed increase is set at 3 W/K.

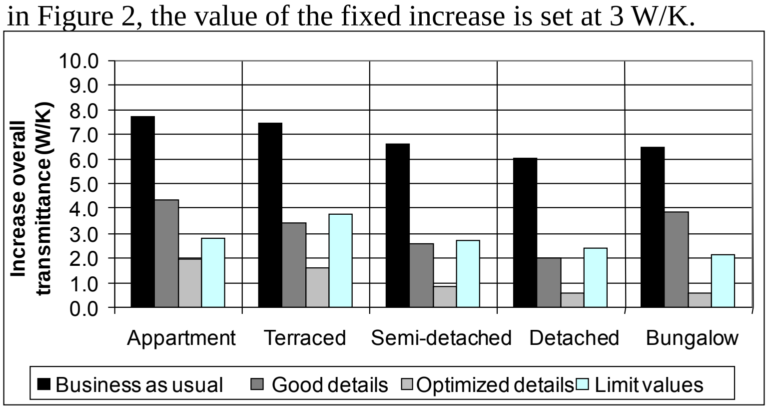


FIG 2. Impact of thermal bridging on the overall heat transmittance for different types of Belgian dwellings. Even with good or optimized details a small increase of the overall transmittance is observed.

This fixed value does of course not correspond to the exact extra losses for every building, but is a pragmatic compromise between a slight overestimation of the heat losses and the advantage not having to calculate any detail, nor length or number of the thermal bridges.

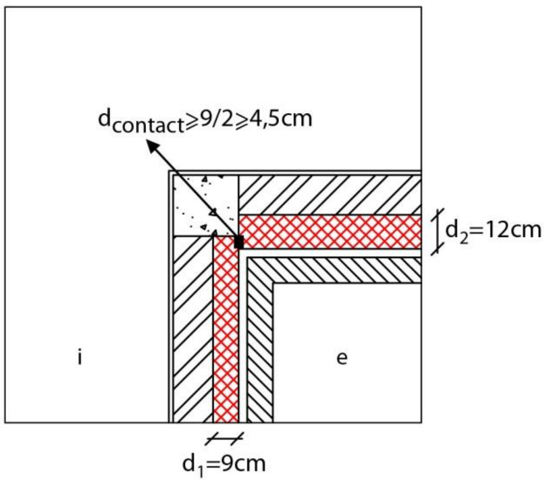
Thermal bridges that do not fulfil the continuity criteria have to be taken into account as in option A.

The last option, option C, applies a large fixed penalty on the overall thermal transmittance. In this option, no attention has to be paid to the thermal bridges (nodes may be designed and constructed in a poor thermal manner and no calculations concerning thermal bridges have to be performed), but the large fixed penalty (10 W/K) on the overall thermal transmittance has to be compensated for by a strong increase of the insulation of the different building envelope components.

4. The simplified approach: EPB-accepted nodes

The option of the EPB-accepted nodes is a pragmatic approach to increase the awareness of good thermal detailing. The basic rules are defined in such a way that designers, contractors and inspectors can - mainly in a visual way - control whether a detail fulfils the requirements to be an EPB-accepted node. Essentially, the basic rules guarantee a continuous insulation layer within the building envelope:

- **Basic rule 1: minimal contact length**. This rule requires that two connecting insulation layers need a sufficient contact length, which is at least half the thickness of the thinnest insulation layer. The contact length criterion followed from detailed calculations for all kind of different junctions, which showed that when the contact length is at least half the thickness of the thinnest insulation layer, the extra losses at the junction were minimal. Furthermore, this way, the rule is made relative to the thickness of both insulation layers. Figure 3 illustrates basic rule 1 for some typical connections.



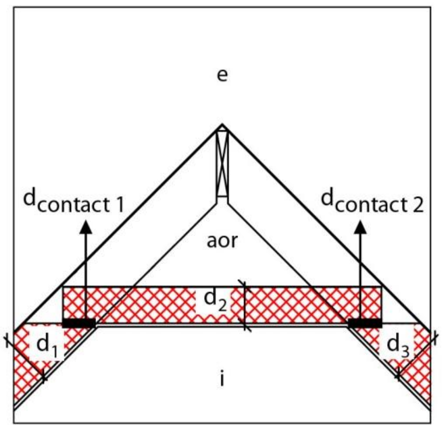


FIG 3. Examples of basic rule 1. Left: horizontal section of a structural column at the inner corner of a cavity wall, right: vertical section of an attic floor (i corresponds to the interior side, e to the exterior). The thermal performance of nodes is guaranteed by a sufficient contact length ($d_{contact}$) at the connection of the different insulation layers: $d_{contact} \geq min(d_1/2,d_2/2)$ with d_1 and d_2 the thickness of the insulation layer in the connecting building elements.

- Basic rule 2: insertion of insulating elements. When at a junction of two building envelope parts, it is not possible to bring the insulation layers within each element in contact with one another, an intermediate insulating element has to be foreseen that fulfils certain requirements:

the thermal conductivity of the intermediate element has to be less than 0.2 W/mK, the thermal resistance of the intermediate element has to be at least half the smallest thermal resistance of the adjacent insulation layers and the contact length between insulating elements and adjacent layers has to fulfil basic rule 1.

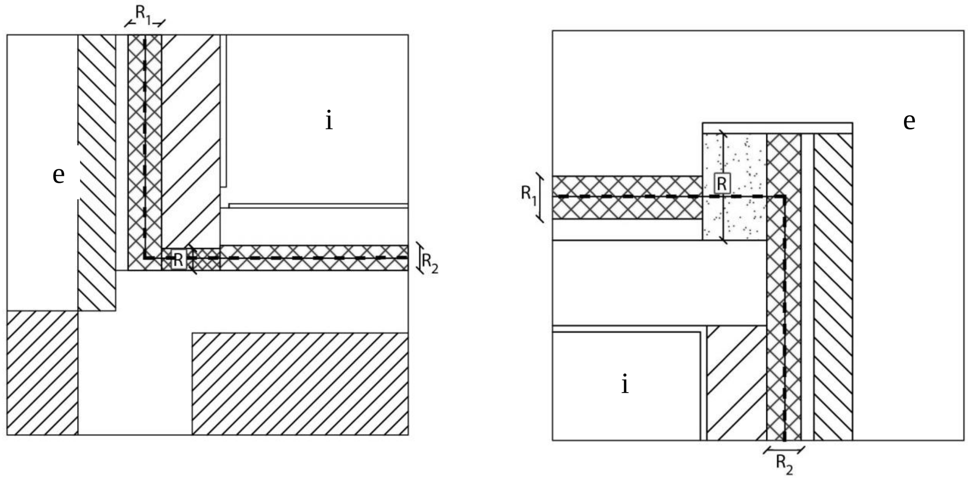


FIG 4. Examples of basic rule 2: at the connection of envelope parts the continuity of the insulation layer is guaranteed by an intermediate insulating element. Left: vertical section of a thermal break at the foundation of cavity wall, right: vertical section of the junction between a flat roof and cavity wall.

It was found that with these basic rules most of the connections and nodes appearing in the building envelope could be covered with an acceptable thermal performance level. However, for some junctions where the continuity of the insulation layer cannot be guaranteed due to structural requirements (e.g. foundations bearing a heavy load, certain wall-floor connections and balconies), basic rule 1 and 2 are often not applicable. To avoid also for those details complex and time-consuming calculations, while still promoting a good thermal performance, a third rule has been added:

- Basic rule 3: path of minimal thermal resistance. Basically, this rule states that if the continuity of the insulation layer is not possible, the heat flow path from inside to outside (bypassing the insulation) needs to be sufficiently long. Figure 5 illustrates this third rule. To determine the necessary length, different typical details have been numerically calculated to determine the linear heat transmission coefficient as a function of the length of the heat flow path. Figure 6 shows the obtained results for a balcony and an overhang. It can be seen that once the path length exceeds 1 meter, the linear thermal transmittance is no longer influenced by the extra insulation layer. Therefore, the required minimal path length was set to 1 meter. Though certainly not the best option, at least basic rule 3 makes it possible to account for those situations where the only solution exists in wrapping insulation around the thermal bridge.

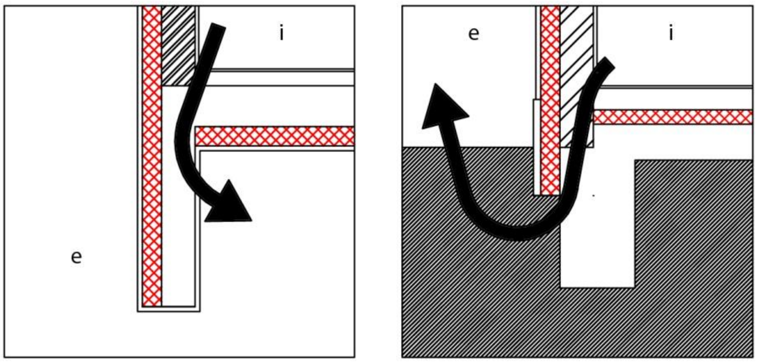


FIG 5. If the continuity of the insulation layer cannot be realised, basic rule 3 requires that the path the heat flows from inside to outside, while bypassing the insulation, is sufficiently long. Left: vertical section of an overhang, right: vertical section of the foundation of the cavity wall.

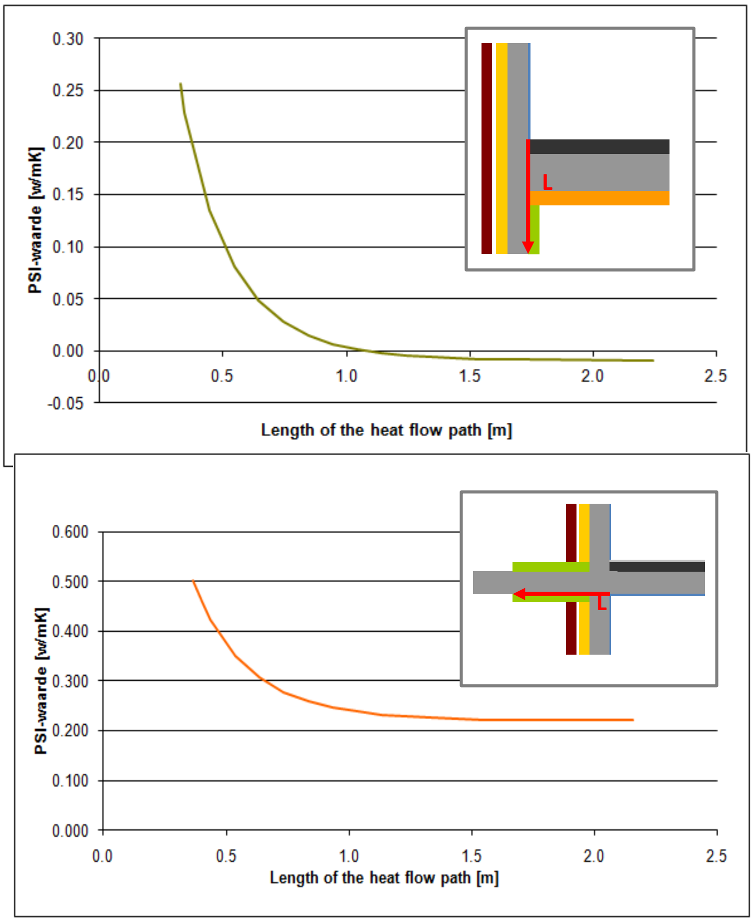


FIG 6. Effect of the minimal path length (outside to inside, bypassing the insulation) on the linear thermal transmittance for an overhang (left) and a balcony (right). Increasing the path length by adding additional insulation along the thermal bridge is mainly advantageous for smaller path lengths, as soon as the path length exceeds 1 meter, the effect of any further increase becomes negligible.

This set of three basic rules is defined in such a way that they can be easily communicated to the building industry and that details can be checked during design and construction phase without any additional calculations.

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. The limit value is depending on the type of thermal bridge. An overview of the limiting values is given in Table 1. This allows for instance building industry to provide specific thermal bridge atlases that can be applied without any further calculations. Note that in Belgium the heat losses are calculated based on exterior dimensions, which results in possible negative values for the linear transmittance coefficient.

TABLE 1. Limit values of the linear transmittance coefficient

Type of thermal bridge	Limit value
1. External corners	
- wall/wall connection	-0.10 W/m.K
- other external corners	0.00 W/m.K
2. Internal corners	0.15 W/m.K
3. Wall/window and wall/door junction	0.10 W/m.K
4. Foundations	0.05 W/m.K
5. Balconies	0.10 W/m.K
6. Others	0.00 W/m.K

Figure 7 summarises the different options for the recognition of a thermal bridge as EPB-accepted node in the new Belgian EPB-regulation.

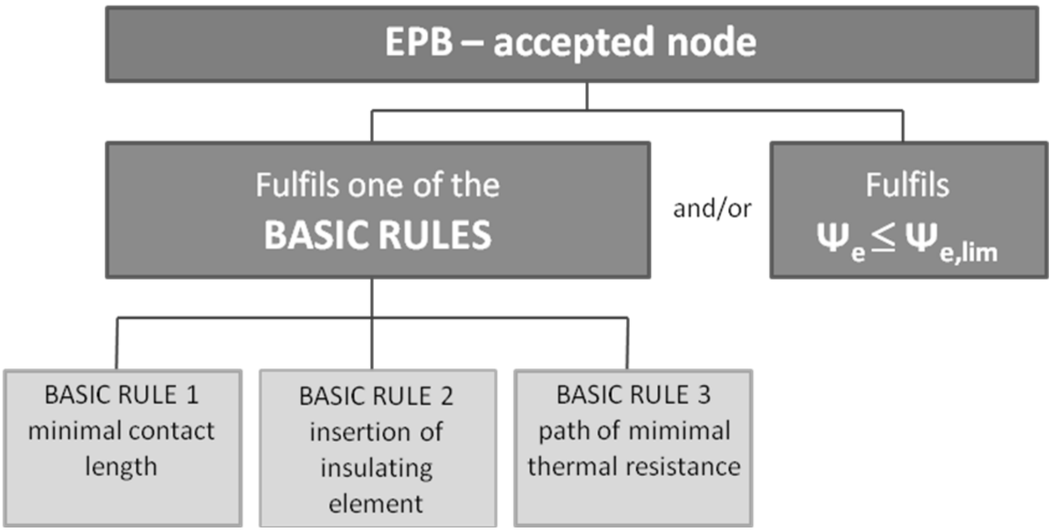


FIG 7.Option for the recognition of a thermal bridge as an EPB-accepted node in the new Belgian EPB-legislation.

5. Conclusions

As previous studies showed that the influence of thermal bridges occurring in the building envelope can be of major importance for the global energy performance of buildings, most European member states impose requirements on the heat losses through thermal bridges in their energy performance legislation. In the Belgian context nor the detailed analysis, nor a thermal bridge atlas was found to be a realistic approach to incorporate thermal bridge requirements in the EPBD-regulation.

Instead a pragmatic approach has been developed in a collaboration between the different regional governments and research institutes. The methodology foresees three main options to take thermal bridges into account: the traditional detailed calculation method, a pragmatic method based on simple basic rules and a penalisation method when no attention is paid to thermal bridges. Mainly the pragmatic approach was well appreciated by the building industry, since it is based on simple rules which, when followed, do not require any calculation at all. Essentially, the basic rules guarantee a continuous insulation layer within the building envelope. The 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 inspectors to control, mainly in a visual manner, whether a 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.

6. Acknowledgements

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