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Methods to include the influence of thermal bonds on the calculation of the energy performance of buildings and their influence on the heat demand for building heating

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Abstract. The paper deals with the effect of thermal bonds on heat transmission of a building envelope. Then it deals with ways to include of thermal bonds in the calculation of heat loss through the building envelope and the calculation of energy efficiency of buildings. A solution of thermal bonds is very important, because it fundamentally influences the energy efficiency of the buildings. It is important to realize that building envelope comprises not only the peripheral surface structures but also thermal bonds in areas where building structures join.

1. Introduction

Nowadays the emphasis is put on reducing the energy performance of buildings [1], which is influenced by the so-called the envelope of the building, which means the perimeter structures at the boundary of the heated zone and outside or unheated space. These building structures are strictly evaluated in terms of thermo-technical qualities. When designing buildings, care must be taken to ensure that these qualities are as good as possible. This means that they try to achieve the lowest values of the coefficient of heat transfer in the U constructions [2]. However, it is necessary to solve the constructions in a complex way, including the right solution of the details [1]. Although the peripheral structures will have excellent thermal insulation qualities, this does not mean that the envelope of the building is designed properly. The quality of the building details solution significantly influences the resulting energy demand of the building, especially for low energy and passive objects [1, 3].

2. Thermal bonds

Thermal bonds are defined according to ČSN 73 0540-1 as boundary between two or more structures, which can be of a point or linear character (point and linear thermal bonds). In these places, the heat flux is significantly altered due to their interaction. Thermal bonds affect thermal flux through the building jacket, especially in buildings with low energy performance. The building envelope can not be perceived only as a summary of the perimeter structures, but as a system of perimeter structures with two-way systemic thermal bonds. However, the design of structural details - thermal bonds is not a regular part of the project documentation, although it is an important part of it. Due to the improper design or construction of the incorrect construction details, the thermal flow is increased by thermal bonding. Examples of wall-ceiling thermal bonding are shown in Figure 1.

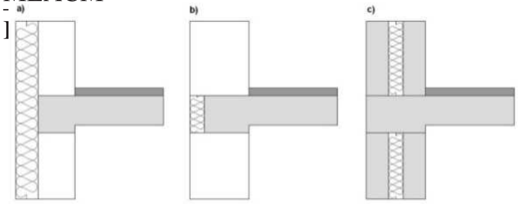

Fig. 1 : Example of thermal bonding: a) Dragging of thermal insulator on the outside of the structure, b) Insertion of heat insulator at the place of thermal bonding, c) Neglected thermal bonding solution in panel sandwich construction

A panel house can serve as an example of poorly designed and neglected building details. The part of sandwich peripheral structures, were thermal insulators and the perimeter structures had good thermal-technical qualities, but the thermal bonding were very neglected. This fact led to a significant increase in the heat flow at those parts of the constructions and to the increase of the energy performance of the building. At the same time, the increased heat flux was manifested by troubles - mildew growth, which had a negative effect on the indoor environment. Fig. 2 shows an increased heat flux through thermal bonding.

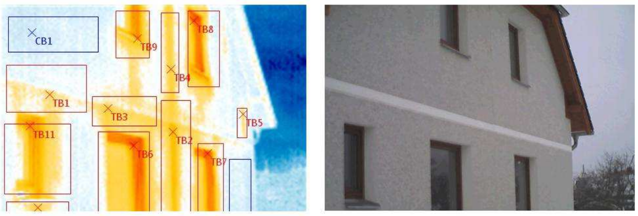

Fig. 2: Thermal imaging of a panel house (increased thermal flow in the place of thermal bonds - contact of panels, ceiling and perimeter walls)

3. Including the influence of thermal bonds on calculation of heat transfer through the building envelope

When calculating the thermal flow through the envelope of the building, which is further applied in the calculations of the heat losses, the energy performance of the building and the average coefficient of heat transfer, it is possible to include the thermal bonds in two ways [5]. The influence of thermal bonds in these calculations includes so-called average influence by thermal bonds.

3.1. Simplified possibility to include the influence of thermal bonds

The easiest way is to roughly include thermal bonds in the calculations with an approximate value that increases the heat flow rate by building envelope by type of building. This is the most commonly used method, however, the results of experimental calculations point to the crucial effect of such a method of including thermal bonds on inaccuracies in heat penetration calculations through the building envelope. The calculation of the specific heat loss in this case is determined by the relationship (1).

$$H_T = \sum \left(U_j \cdot A_j \cdot b_j\right) + A \cdot \Delta U_{tbm} \quad (1)$$

, where H_T is specific loss of heat transfer (W/K)

U_j heat transfer coefficient of construction "j" (W/(m^{2}K))

A_j the surface of the cooled structure "j" at the system boundary of the building envelope (m^2)

b_j thermal reduction factor of construction "j" (-)

ΔU_{tbm} the average influence of thermal bonds between cooled constructions on the system boundary of a building (W/(m^{2}K))

A the area of all cooled structures at the system boundary of the building envelope (m^2)

In the case of this simplified calculation, the values are considered as follows:

- ΔU_{tb} = 0,02W/(m^{2}K)) for buildings with consistently optimized thermal bonding, this value is commonly used for new buildings.
- ΔU_{tb} = 0,05W/(m^{2}K)) for buildings with mild thermal bonds, this value is commonly used for insulated buildings.
- ΔU_{tb} = 0,10W/(m^{2}K)) for buildings with normal thermal bonding.
- ΔU_{tb} = 0,20W/(m^{2}K)) and more for neglected solutions.

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3.2. Exact inclusion of the influence of thermal bonds

For a more accurate calculation, however, it is possible to make a calculation by precise input of thermal bonds [4], where the thermal flux through thermal bonding and its length (in the case of point thermal bonding his count) is taken into account. Calculation of specific heat loss through heat transfer is then performed according to the relationship (2).

$$H_T = \sum \left(U_j \cdot A_j \cdot b_j\right) + \sum \left(\psi_j \cdot l_j \cdot b_j\right) + \sum \left(\chi_j \cdot b_j\right) \tag{2}$$

, where H_T is specific loss of heat transfer (W/K)

U_j heat transfer coefficient of construction "j" (W/(m^{2}K))

A_j the surface of the cooled structure "j" at the system boundary of the building envelope (m^2)

b_j thermal reduction factor of construction "j" (-)

ψ_j linear factor thermal transmittance linear thermal bond "j" (W/(m·K))

l_j the length of the linear thermal bond "j" between the structures within the building (m)

χ_j point factor thermal transmittance of the j-point thermal bond between buildings within the building (W/(m^{2}K))

All thermal bonds that are part of the building envelope considered must be included in the calculation. This can be complicated in buildings of non-compact shape. The linear and point heat transfer factors are input into the calculation. Their quantities are determined by calculation based on thermal bonding. At thermal bonding sites multidimensional heat dissipation takes place and calculation of thermal permeability can only be done by solving the so-called thermal field. The calculation is done using finites elements software and is time consuming.

4. Heat flow through the envelope of the building

Thus, the choice of the method of incorporating the influence of thermal bonds can significantly influence the calculation of heat flow through the envelope of the building envelope. This is especially important for the evaluation of the thermal-technical properties of the whole envelope of the building using the so-called average coefficient of heat transfer U_{em}, but also for calculating the heat losses and energy performance of buildings. The difference in the calculation will not be noticeable in the case of buildings that do not have thermal-technical properties at the low energy standard level. However, in the case of low-energy and passive houses [1], the specific heat flux through the thermal bonds forms a significant share of the total heat flow through the building envelope. In the case of these buildings, it is important to emphasize on right solution the thermal-technical of thermal bonds to avoid increased heat fluxes. Experimental calculations have shown that in passive buildings the choice of the method of incorporation of thermal bonds is essential and will affect the specific heat demand for heating E_a [6].

4.1. Heat demand for heating

Thermal loss characterizes the thermal flow of the building under extreme conditions. The heat demand for heating is determined by the amount of energy required to maintain a pleasant indoor temperature. The specific heat demand for heating is rated. This variable is not dependent only on the properties of the building envelope, but also on other parameters, such as the way of ventilation and thermal gains of the building. In the case of passive houses, it has been shown that due to the precise inclusion of thermal bonds in the calculation of the energy intensity, there is usually a difference of about 5 kWh/(m^2.year) in case of a specific annual heat demand for heating E_a. The specific heat demand for heating a passive house is max to 20 kWh/(m^2.year). Thus, the difference between the results according to the way of incorporating the influence of the thermal bonds can thus account for up to 25% of the total heat demand for heating [3], assuming a high quality thermal bonding. In the passive houses, we solve the details so that there is no increase in thermal bonds [1]. The use of a flat rate then significantly increases the heat flux that is not actually occurring. In the case of the energy performance assessment of the passive building, it is therefore advantageous to make a precise calculation of the influence of the thermal bonds. Figure 3 shows a graphical representation of the temperature field, the calculation of which was made to accurately include the influence of thermal bonds in the calculation, several building details of the passive house.

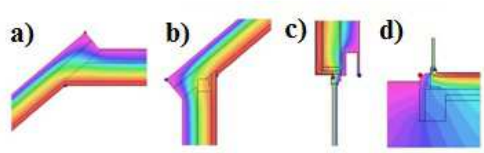

Fig. 3: Graphical representation of the thermal field of several building details of the passive house (thermal bond: a) oblique roof and ceiling under unheated soil, b) perimeter wall and oblique roof in the place of the wall plate, c) the perimeter wall and the window top, d) the floor and door threshold)

5. Experimental analysis

For three types of family houses, the calculation of the energy performance was always performed with the inclusion of thermal bonds in a simplified and detailed manner. The calculation was made for a typical non-insulated existing house and for the new building of brick and lightweight perimeter constructions.

5.1. Computational model

The energy performance of buildings is also influenced by the so-called volume factor of the A / V building shape. Four models of family houses were was created, see Fig. 4. The building factor volume factor determines the ratio between the total area of the building envelope and the outside volume of the heated zone. The lower the volume factor, the more energy-efficient the building is. The less compact buildings have a larger amount of thermal bonds.

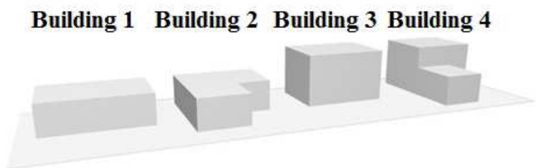

Fig. 4: Computational building models

Table 1: Influence of the compactness of the house on the volume factor

Model	Volume factor *A/V* [-]	Description
1	0,97	Single-storey building of compact shape (bungalow type)
2	1,00	Single-storey L-shaped building (bungalow type)
3	0,79	Two-storey building of compact shape
4	0,88	Two-storey building of non-compact shape

The calculation was made for three houses. The first is a brick family house, a perimeter construction typical of houses built around the 1950s. The other two models are a typical new building whose perimeter construction is at the level of passive buildings. The model was designed for the construction of masonry with ETICS and for a light wooden structure. For the simplified method of incorporating the influence of thermal bonds, the values ΔU_{tb} = 0,10 W/(m^2.K) for the existing insulated building and ΔU_{tb} = 0,02 W/(m^2.K) for new buildings. In case of accurate inclusion of the influence of thermal bonds, the values of linear heat transfer factors ψ, which were calculated based on the results of two-dimensional temperature field solution for typical solution of building details for the given building type, were considered.

5.2. Calculation results

The results of the calculations are shown in Tab. 2 As an evaluation criterion, the annual specific heat demand for heating E_a v kWh/(m^2.year) was chosen. In the case of new buildings with well-designed details, the method of determining the influence of thermal bonds can significantly influence the results of the calculation. At the same time, of non-isolated existing buildings, the differences in the calculation results are not so severe. In this case, the calculation result may even deteriorate due to poorly solved thermal bonds.

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Table 2: Specific heat demand for heating by specific and exact calculations

Type of building	Method of calculating the influence of thermal bonds	Specific heat demand for heating E_a (kWh/(m$^{2\cdot}$year))			
		1 A/V = 0,97	**2** A/V = 1,00	**3** A/V = 0,79	**4** A/V = 0,88
Existing bricked	Simplified ΔU_{tb} = 0,10 W/(m$^{2\cdot}$K)	349	362	263	302
	Exact by ψ	337	350	268	304
New bricked	Simplified ΔU_{tb} = 0,02 W/(m$^{2\cdot}$K)	45	45	31	35
	Exact by ψ	38	38	28	30
New (light const.)	Simplified ΔU_{tb} = 0,02 W/(m$^{2\cdot}$K)	52	53	37	41
	Exact by ψ	43	47	31	35

6. Conclusion
The article deals with the influence of thermal bonds on two-way heat penetration through the envelope of the building. It emphasizes that the envelope of the building is not only created by its flat construction, but also by thermal bonds. Percentage increase depends only on the general solution of thermal bonds. The article shows that the flat increase can be very inaccurate and it is only an indicative determination of the influence of thermal bonds. More precise results can be obtained by specifying the influence of thermal bonds by means of linear and point heat transfer factors. This procedure is time consuming and is almost unused in practice. The part of the article is an analysis of the influence of the method of assigning thermal bonds to calculation of thermal flux through the building envelope. The results have shown that in the case of thoroughly solved thermal bonds, it is appropriate to perform the calculation by accurately determined influence of thermal bonds. Quality of the solution of the building details has a crucial influence on the energy performance of the building and it shows how important it is to think of the correct implementation of the building details.

7. References
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