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DEFINING OF THERMAL BRIDGES OF WOOD BUILDING AND THEIR ELIMINATION

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ABSTRACT

The thesis focuses on the matter of thermal bridges in case of wooden panel structures, both in case of low-energy and passive structure-standard. Thermography was used for localization of critical areas of structures – details of corner joints of external walls and ceiling connections. The values subject to comparison are the linear coefficient of heat penetration from the exterior and the lowest interior surface temperature. This results in the overall comparison of both the structures as well as elimination of the excessive heat flow, whereas the difference in detail of corner joints of external walls is 0.03 W.(m.K)$^{-1}$ for both, and the difference in detail of the ceiling connections equals 0.07 and 0.08 W.(m.K)$^{-1}$ respectively. The difference in the lowest interior surface temperature in detail of corner joints of external walls for both structures equals 1.34 and 2.99°C respectively, and in the detail of the ceiling connections the difference is 2.45°C.

KEYWORDS: Thermal bridges, wooden house, low-energy house, passive house.

INTRODUCTION

The popularity of wooden buildings in the Czech republic already approaches the European standards. Some countries have already planned to reach an increase in wooden family houses share by a kind of a national program through housing subsidies and public campaigns – as an expression of society responsibility towards natural and power sources (Pfeifer et al. 1998).

Buildings are designed in such a way so as to have low heat needs for heating purposes and so as to arrange thermal protection in compliance with required standard values and regulations in case of setting more strict requirements. A correct thermal technical design should secure development of a complex thermal insulating case of a building with minimal number of weak points, i.e. thermal bridges. The matters of thermal bridges are defined by our national standards ČSN 73 0540-1 (2005) and ČSN 73 0540-2 (2011), as well as by the international standard ČSN EN ISO 14683 (2009), providing means for assessment of contribution of construction elements and technical equipment to power savings and general level of building demands.

Thermal bridges that generally appear between connections and joints of construction parts or in locations of changes in building structures or changes of geometry, have – in comparison with constructions without thermal bridges – two significant consequences, i.e. the change of thermal flow density and surface temperature change. Basically, according to TNI 73 0329 (2010) we distinguish two types of thermal bridges according to geometry:

- linear thermal bridge with identical sections in one direction;
- point thermal bridge without identical sections in any direction.

In construction practice, it is usually possible to encounter thermal bridges in constructions caused by heat conduction (Incropera and De Witt 2011). Due to exceptional insulation abilities of modern construction materials, the heat consumption of a wooden house is quite significantly affected by thermal bridges, respectively by thermal relations between constructions (Pérez-Lombard et al. 2008). The composition of layers still remains to be the base of the construction design and its characteristics, but the design and inclusion of influence of thermal bridges contained in the construction is of at least the same importance. Thermal bridges are more important in constructions for low-energy houses. According to Lupíšek et al. (2015), a low-energy house is considered to be the house with heat needs for heating reaching the value of 50 kWh.(m^2.a)$^{-1}$ as a maximum and a passive house is considered to be the house with maximal heating need of 15 kWh.(m^2.a)$^{-1}$. It is not possible to make do with extensive designing of insulation thicknesses with minimal heat conductivity possible, but it may be more important to eliminate or optimise the thermal bridges in the construction and specific details. Decreasing the importance of thermal bridges in construction details may be more efficient and cheaper way towards improvement of thermal insulation characteristics of a building shell (Totten et al. 2008). Heat permeability through outer shell is then defined by the following relation:

$$H = \sum U_i A_i + \sum \Psi_k l_k + \sum \chi_j \quad (\text{W.K}^{-1}) \tag{1}$$

where: U_i – heat penetration coefficient of parts and outer shell of a building (W.(m^2.K)$^{-1}$),
A_i – area which it applies to U_i (m^2),
Ψ_k – linear coefficient of heat penetration of a thermal bridge k (W.(m.K)$^{-1}$),
l_k – length which it applies to Ψk (m),
χ_j – point coefficient of heat penetration of a thermal bridge j (W.K^{-1}).

The principles of proposed construction details are based on the fact that designed details must correspond with requirements, they must be performable and it must be the simplest possible solution (O'Brien 2005).

Thermal bridges cause increase heat penetration as well as decrease of surface temperature in the thermal bridge area. The condition may be connected with internal humidity supply (Dohnal and Pěnčík 2016), interior air temperature and heating system type and it may cause surface condensation of interior humidity (ČSN EN ISO 13788 2013). In case of this condition to occur there appears a risk of moulds development and bacteria propagation.

Linear coefficient of heat penetration

Regarding required maximal values of linear coefficient of heat penetration of thermal bridges and reaching the low-energy and passive level, special attention must be paid to each and every characteristic detail of the realised construction. The linear coefficient of heat penetration of thermal relations between constructions must meet the following condition:

$$\Psi \leq \Psi_N \qquad (2)$$

where: Ψ_N – required value of linear coefficient of heat penetration (W.(m.K)$^{-1}$).

The above stated relation is applied even in the design and assessment of thermal relations between constructions to recommended values of linear coefficient of heat penetration.

Minimal interior surface temperature in the area of a thermal bridge

In winter periods, the engineering constructions in premises with relative humidity of interior air below 60 % must show in each and every location the interior surface temperature pursuant to the following relation:

$$\Theta_{si} \geq \Theta_{si,N} \qquad (3)$$

$$\Theta_{si,N} = \Theta_{si,cr} + \Delta\, \Theta_{si} \qquad (^\circ C) \qquad (4)$$

where: $\Theta_{si,cr}$ - critical interior surface temperature, at which the interior air of designed temperature and designed relative humidity reaches critical interior surface humidity (°C),
$\Theta_{si,cr}$ - critical interior surface humidity is the relative humidity of air immediately next to the interior surface of the construction, which is not allowed to be exceeded for given construction (%),
$\Delta\, \Theta_{si}$ - safety temperature surcharge taking into consideration the way of interior space heating and thermal persistence of the construction (°C).

There is always checked the lowest of all the established temperatures. Fulfilment of the above stated requirement towards the lowest surface temperature excludes the risk of surface condensation of water steam and that the prevention of moulds development.

The paper aims at definition of thermal flow at critical details with setting the linear coefficient of heat penetration from the exterior and the lowest interior surface temperature, all of that for low-energy and passive wood construction of a building company in the Czech republic.

MATERIAL AND METHODS

There was selected the following methodological procedure of investigation and elimination of thermal bridges in low-energy and passive construction:

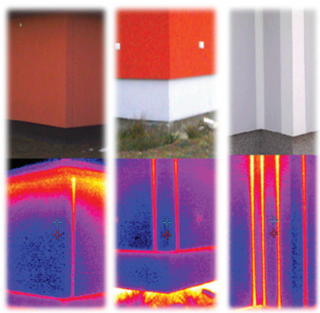
- preparation before the proper thermo-visual measuring – analysis of possibly problematic spots;
- thermo-visual measuring of panel wooden buildings;
- detection and assessment of critical characteristic details;
- laying down the selected characteristic details;
- checking of selected details using the software AREA 2010 – calculation of two-dimensional stationary field of temperatures and establishment of linear heat penetration coefficient from the exterior;
- design and laying down the selected eliminated characteristic details;

- checking of selected eliminated details using the software AREA 2010 – calculation of two-dimensional stationary field of temperatures and establishment of linear heat penetration coefficient from the exterior;
- general comparison and assessment of eliminated thermal bridges for both of the constructions.

During specific assessment of characteristic details of low-energy and passive construction there were selected two standardized two-floor family houses based on wood, performed using the panel construction system. It is very common construction system in wooden structures (Moga and Moga 2015). One of them is low-energy and the other with passive construction. The occurrence of thermal bridges in the wooden buildings is specific due to the fact that the construction system uses large quantities of auxiliary materials for consequent connection of individual pre-fabricated construction elements at the construction site, it also supported by the results of Capozzoli et al. (2015). The auxiliary materials are frequently made of aluminium (corner joints, foundation ledges for the facade system, etc.), which is a very good thermal conductor. In the locations of main facade insulation layer interruption there develops excessive thermal flow and a thermal bridge develops in that spot. The spots are eliminated by a change of assemblage, i.e. removal of auxiliary aluminium materials and arrangement of non-interrupted heat insulation layer.

A highly provable possibility of detecting – after finishing the construction works – any possible location of a thermal bridge and its exact localisation is the thermo-vision technology (Bianchi et al. 2014). A special thermo-vision camera may be used under suitable temperature conditions for the increased thermal flow to be seen. The thermo-graphic recording was performed in the course of a cold period at the beginning of the year 2013.

The corner joint detail of external walls was not solved by standard corner, but with connection from one side of the house only (Fig. 1a). In standard maintenance of production technology and the subsequent construction of prefabricated panels, these sites are a significant weakening of the building in terms of leakage of thermal energy from the object (Fig. 1b and Fig. 1c).



(a) (b) (c)

Fig. 1: Thermo-graphic photographs of the corners connection (a, b, c).

The external temperature on the date of measuring was approximately -15°C and supposed temperature of interior environment of measured family houses, built using the panel construction system, was between 19 and 23°C. Thanks to the thermo-graphic photographs taken, there were established the critical location of excessive thermal power leakage from the construction to the external environment. Based on thermo-visual measuring results assessment there was performed check and elimination and there were selected the details for the low-energy and passive construction:

A - detail of corner joint of external walls;

B - detail of ceiling connection on the first floor.

Regarding passive construction these are:

C - detail of external wall connection to the base plate;

D - detail of wall and ceiling connection on the second floor;

E - detail of window placement at the window sill.

Just for clarity, each detail was marked with number 1 before elimination and with number 2 after elimination of thermal bridges. Each and every investigated detail was designed as a section of given location, i.e. with two dimensions only. Selected details were checked by the program AREA 2010, allowing calculation of a two-dimensional stationary field of temperatures and it consequently generates graphic outputs of the temperature field.

RESULTS AND DISCUSSION

Shape and geometrical solution of a detail is always the most important feature for maximally precise calculation of linear coefficient of heat penetration from the exterior. The linear coefficient of heat penetration at individual details may be positive or negative, as it can be seen in Tab. 1.

Tab. 1: General comparison of linear coefficient of heat penetration.

Investigated detail before and after elimination of a thermal bridge	Linear coefficient of heat penetration from the exterior Ψ_e (W.(m.K)$^{-1}$)				Linear coefficient of heat penetration (W.(m.K)$^{-1}$) according to ČSN 73 0540-2		
	Low-energy before	Low-energy after	Passive before	Passive after	Required values Ψ_N	Recommended values Ψ_{rec}	Recommended values for passive Ψ_{pas}
Det. A1 + A2	0.11	0.08	0.08	0.04	0.2	0.1	0.05
Det. B1 + B2	0.1	0.03	0.07	-0.01	0.2	0.1	0.05
Det. C1 + C2	-	-	0.01	-0.03	0.2	0.1	0.05
Det. D1 + D2	-	-	-0.02	-0.04	0.2	0.1	0.05
Det. E1 + E2	-	-	0.06	0.03	0.1	0.03	0.01

More frequent positive value at individual details means that an additional loss occurs via the assessed thermal bridge. According to Pospíšil and Pěnčík (2013), less frequent negative value means that the influence of assessed thermal bridge on total thermal loss of the house is in fact already contained in the thermal loss via the area constructions of the building shell. In case of details B and C of the passive construction, the thermal bridge was so successfully eliminated that in given detail location there does not occur excessive heat flow towards the exterior and so there does not appear undesirable thermal loss due to imperfect thermal relation of the detail, as is asserted in the work of Sprengard and Holm (2014). All and any assessed details meet the standardized required values of linear coefficients of heat penetration according to the standard ČSN 73 0540-4 (2005).

In case of detail A1 (Fig. 2) of the low-energy construction, there is an apparent increased heat flow due to the additional slip-over corner used, containing the aluminium fixation profile.

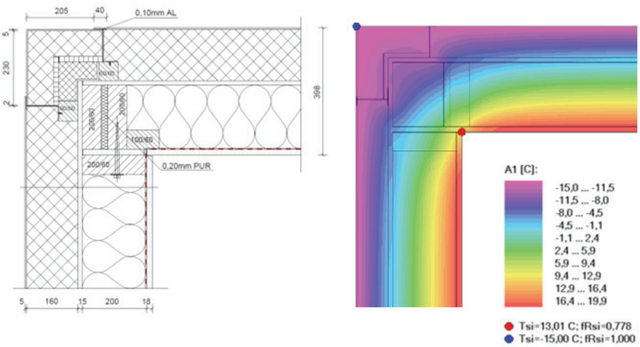


Fig. 2: The corner joint detail A1 of low-energy house without elimination thermal bridge.

In case of eliminated thermal bridge at the detail A2 (Fig. 3), the calculated value of linear coefficient is in 0.03 W.(m.K)$^{-1}$ better than at A1 thanks to non-interrupted contact thermal insulation layer.

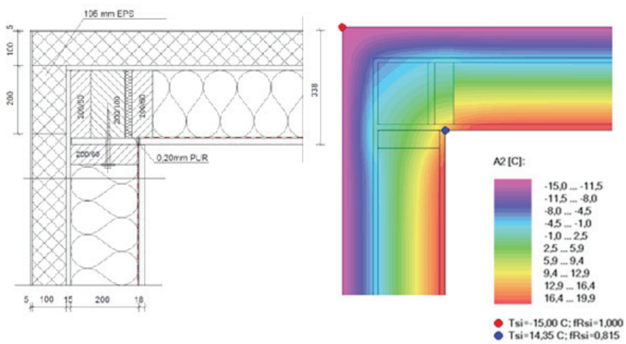


Fig. 3: The corner joint detail A2 of low-energy house with elimination thermal bridge (a, b).

The interior minimal surface temperatures of all the assessed details were successfully increased in favour of water steam condensation reduction, as shown in Tab. 2.

Tab. 2: Minimal interior surface temperature.

Investigated detail before and after elimination of a thermal bridge	**Minimal interior surface temperature Θ_{si} (°C)**			
	Low-energy before	**Low-energy after**	**Passive before**	**Passive after**
Detail A1 + A2	13.01	14.35	15.14	18.13
Detail B1 + B2	14.59	17.04	15.79	18.24
Detail C1 + C2	-	-	18.1	19.27
Detail D1 + D2	-	-	17.93	18.57
Detail E1 + E2	-	-	12.08	12.23

The calculated minimal interior surface temperature of the low-energy construction at detail A2 is 14.35°C, which is sufficient with 50 % relative humidity in the interior and the temperature of 21°C. It is also supported by the results of Buday et al. (2014) and Tenpierik et al. (2008). In case of the A1 low-energy construction detail, the interior surface temperature is 13.01°C, which is less than the limit critical surface temperature 13.6°C. In case of long-term influence of calculation conditions and absence of controlled ventilation of the room there is a risk of water steam condensation.

CONCLUSIONS

The main investigated indicator at compared details of the panel construction is the linear coefficient of heat penetration Ψ_e, which was successfully decreased at each investigated detail. With two investigated details of a passive construction the positive value of linear coefficient of heat penetration was successfully decreased to a negative value, which means that the linear thermal relations with negative linear coefficient would not be considered in consequent calculations of specific heat consumption for heating.

The increased heat flow at low-energy construction of the detail A2 is very significantly eliminated. So as to reach the calculated result it will be necessary to take adequate technological measures in manufacture and assemblage itself. It will be necessary to make the final plaster only at complete assemblage of all the external panels of the wooden building.

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