THERMAL BRIDGES DINAMIC SIMULATION AND HEAT TRANSFER COEFFICIENT VALUE FOR SPECIFIC THERMAL BRIDGES

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KEYWORDS
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ABSTRACT
A thermal bridge is a part of the building envelope where the otherwise uniform thermal resistance is significantly changed by:
• Full or partial penetration of the building envelope by materials with a different thermal conductivity and/or
• A change in thickness of the structure and/or
• A difference between internal and external areas, such as occur at wall-floor-ceiling junctions.

INTRODUCTION

The study of heat transfer in buildings can be achieved by subdividing the structure into wall types (walls, windows, doors, floors and roofs), for which heat losses can be calculated separately. This kind of calculation is normally based on a one- dimensional model, i.e. assuming that the walls are homogeneous and are composed of a number of parallel layers for which the heat flow is perpendicular, as shown in Figure 1.
The heat transfer can be described for such a model, given some simplifications, by the thermal transmittance of the wall (the U-value). This value gives the heat loss through the building element per unit of inside to outside temperature difference and per unit of surface of the building element:

$$U = \left(\frac{1}{\alpha_e} + \Sigma \frac{d_i}{\lambda_i} + R_a + \frac{1}{\alpha_i} \right)^{-1} \text{[W/m²K]} \quad (1)$$

The size of the heat transfer (= the heat loss transmission ϕt) is then given by:

$$\phi_t = U \cdot A \cdot (T_i - T_e) \quad (2)$$

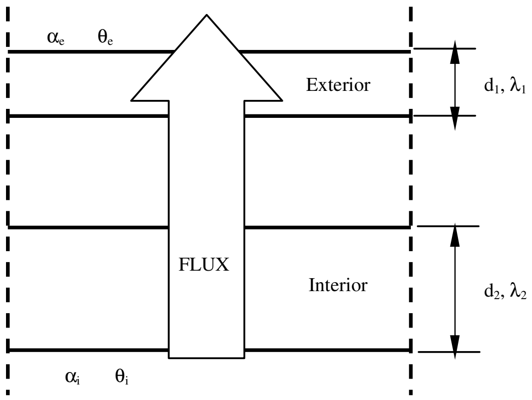

Figure 1. Heat transfer through homogeneous building elements

THERMAL EFFECTS SIMULATIONS DUE TO THERMAL BRIDGES AND DETERMINE THE THERMAL BRIDGES HEAT TRANSFER COEFFICIENT

The thermal effects simulations due to the thermal bridges and the heat transfer coefficients were realized using the dedicated program for buildings thermal bridges simulation Heat 5.0

Thermal effects simulations due to thermal bridges and determine the thermal bridges heat transfer coefficient for an exterior wall without thermal insulation

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The first analyzed structure is an exterior wall in contact with the exterior air and with the ground, without thermal insulation, the second analyzed structure is also for an exterior wall in contact with the exterior air and with the unheated floor basement, with thermal insulation. The considered thermal insulations are the expanded polystyrene and mineral wool.

In Figure 2 is presented the exterior wall without any thermal insulation. The exterior air temperature is T_e=0°C, the ground temperature is T_g= 10°C, and the interior temperature T_i=20°C.

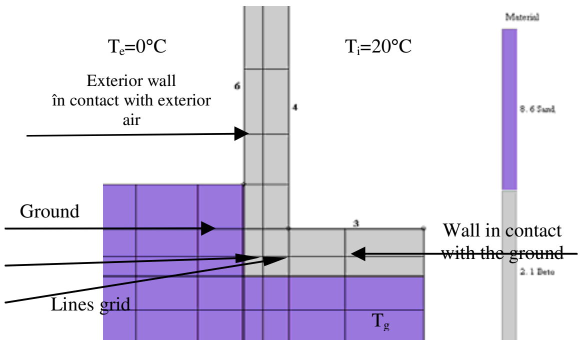

Figure 2. Exterior wall without thermal insulation – floor in contact with the ground, Heat 5.0

The right part of the figure indicates the component materials and the numbers on the figure indicates the wall component surfaces. The wall is made from concrete.

In tables 1 and 2 are presented the heat fluxes values for each part component of the wall and the limit conditions.

Table 1: Heat fluxes values for each part component of the wall and the limit conditions

Wall surface	q[W/m²]	Q[W/m]	Length [m]	Limit conditions
3	1.2775	0.9581	0.75	[2] T=10 R=0.13
4	0.6147	0.922	1.5	[2] T=10 R=0.13
6	-0.1208	-0.1486	1.23	[3] T=0 R=0.04
7	-0.2086	-1.7314	8.3	[3] T=0 R=0.04
Heat transfer sum: 3.6E-5 W/m				
Heat transfer sum: 1.8801 W/m				

Table 2. Heat fluxes for each surface depending on the limit conditions

Heat transfer for each wall surface and the characteristics limits conditions			
Wall surface	q [W/m^2]	Limit conditions	
[2]	1.8801	[2]	(T=10 R=0.13)
[3]	-1.8801	[3]	(T=0 R=0.04)
Sum: 3.6E-5			

In the Figures 3 and 4 are presented the temperatures and heat fluxes variations due to the thermal bridges for the analyzed wall.

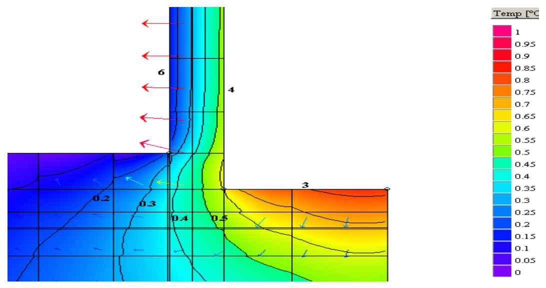

Figure 3: Temperatures variation for the analyzed wall without thermal insulation, Heat 5.0

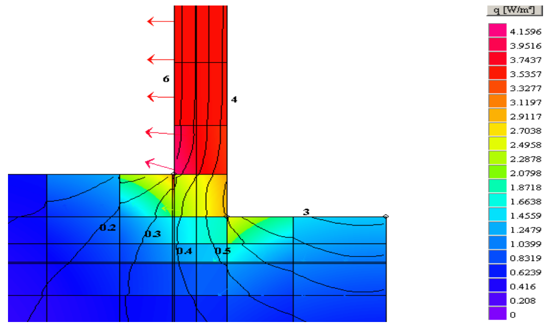

Figure 4: Heat fluxes simulation for the analyzed wall structure, Heat 5.0

Thermal effects simulations due to thermal bridges and determine the thermal bridges heat transfer coefficient for an exterior wall with thermal insulation

The Figure 5 presents the second wall section: the right part of the figure describes the component materials, so depending on the limitations zones the wall includes: 6 surface– expanded polystyrene, 3 and 4 surfaces: concrete, and the ground surface.

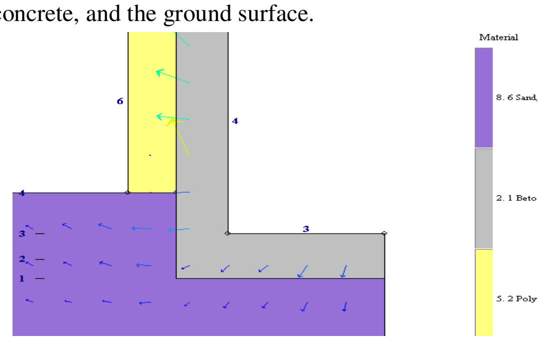

Figure 5: Exterior wall with polystyrene thermal insulation – floor in contact with the ground

Table 3 describes the heat fluxes and the limit conditions for the wall structure presented in the Figure 5.

Table 3. Heat fluxes values for each part component of the wall and the limit conditions

Wall surface	q[W/m²]	Q[W/m]	Length [m]	Limit conditions
3	2.1093	1.582	0.75	[2] T=1 R=0.13
4	2.2503	3.3755	1.5	[2] T=1 R=0.13
6	-0.0574	-0.0706	1.23	[3] T=0 R=0.04
7	-0.3357	-2.7798	8.28	[3] T=0 R=0.04
Unitary heat fluxes sum: 2.1071 W/m^2				
Total heat fluxes sum: 4.9575 W/m				

In the figures 6 and 7 are presented the temperatures and heat fluxes variations due to the thermal bridges for the wall described in the figure 5, exterior wall with polystyrene thermal insulation – floor in contact with the ground.

Figures 8 and 9 present the heat fluxes variations for different wall points of the structure depending on the wall thickness, for the wall structure without thermal insulation (figure 2).

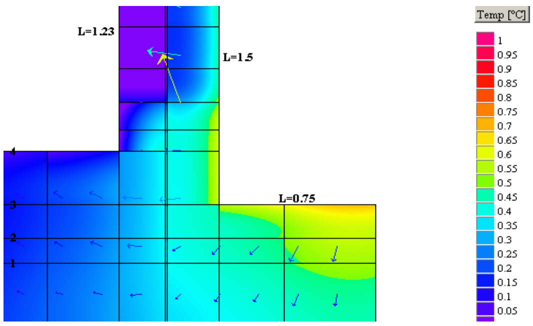

Figure 6. Temperatures variations, Heat 5.0

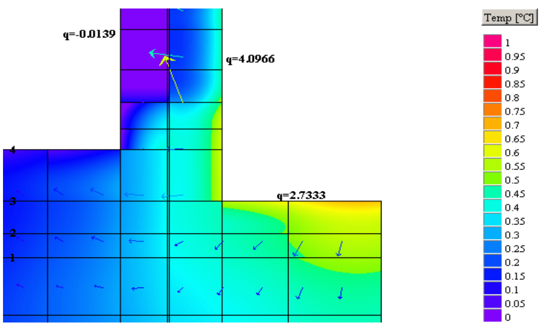

Figure 7. Heat fluxes variations, Heat 5.0

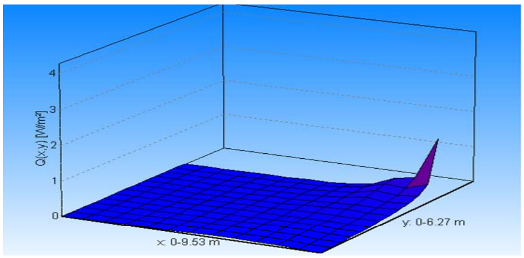

Figure 8. Wall structure without thermal insulation heat fluxes variations in 3D, Heat 5.0,

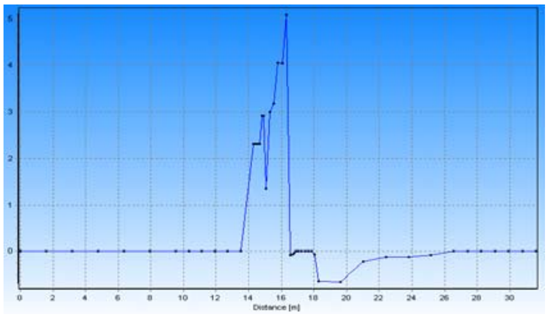

Figure 9. Wall structure without thermal insulation heat fluxes variations depending on the wall

Figures 10 and 11 presents the temperatures variations depending on the wall thickness, in different point of the structure, for the wall structure without thermal insulation (figure 2).

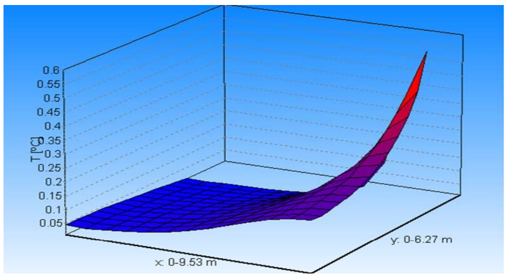

Figure 10. Wall structure without thermal insulation temperatures variations in 3Dimensional domain, Heat 5.0

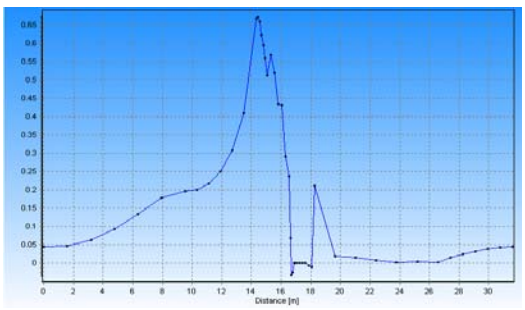

Figure 11. Wall structure without thermal insulation temperatures variations depending on the wall thickness, Heat 5.0

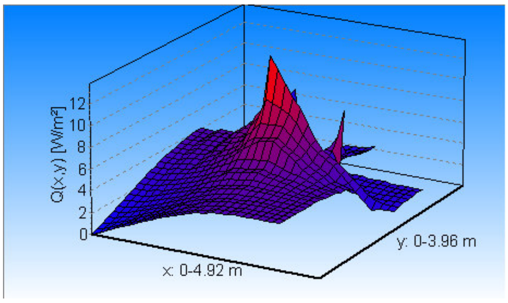

Figure 12. Wall structure with thermal insulation heat fluxes variations in 3D, Heat 5.0

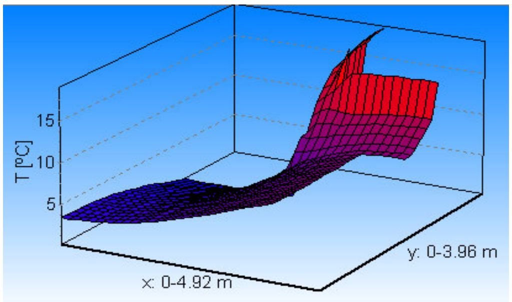

Figure 13. Wall structure with thermal insulation temperatures variations depending on the wall thickness, Heat 5.0

Analyzing and comparing the two structures we can conclude: in the figures 8 and 12 are presents the heat fluxes variations for the two analyzed walls structures in three dimensional domains. For the first wall structure, wall without thermal insulation layer, the heat fluxes' had bigger values comparing to the second structure, the wall case that had thermal insulation layer (polystyrene), resulting that the heat loses for the first wall structure (figure 2) are higher comparing to the second wall structure (figure 5).
The figures 10 and 13 present the temperatures variations in three-dimensional domains for the two analyzed structures presented in the figures 2 and 5. We can observe that in the figure 12, the case of the second wall structure, wall with thermal insulation layer (figure 5) the temperatures are beginning to increase especially on the wall side were the thermal insulation is used, comparing to first wall, that had no thermal insulation, were the temperatures on the wall surface are almost equal to the exterior temperatures. Otherwise, the temperatures for the wall surface in contact with the ground are bigger because the ground temperature is considered 10 °C, and the exterior temperatures is 0°C resulting that the lowest temperatures of the wall structures are registered on the side in contact with the exterior air.
The structures were analyzes using the dedicated simulation program for determining the heat looses due to the thermal bridges influences, Heat 5.0.

THE HEAT LOOSES THERMAL COEFFICIENT DUE TO THE THERMAL BRIDGES EFFECT CALCULATION

The heat looses thermal coefficient due to the thermal bridges effect can be calculated using the formula (3) [DIN EN ISO 10211]:

$$\Psi_a = \frac{Q_{2D} - A_1 \cdot U_1 \cdot \Delta T + Q_{2D} - A_2 \cdot U_2 \cdot \Delta T}{l} \cdot \Delta T_{max(1,2)} \quad [W/mK](3)$$

where:
l_1, l_2 – the lengths for the considered structures, [m];
U_1, U_2 – the two regions thermal transmitances, [W/m^{2}K];
Q_{2D} – thermal flux calculated in the bi dimensional domain, [W];
A_1, A_2 – the surfaces aria, [m^2].
ΔT – temperature difference between interior and exterior air, [K];
l –structure length, [m].
$\Delta T_{max(1,2)}$ – maximum temperature difference between the two considered regions, [K];
ψ_a- the thermal coefficient due to the thermal bridges effects, [W/mK].
For the two considered structures we will determine the thermal looses coefficients due to the thermal bridges effect.
The table 4 and 5 present the heat looses coefficient due to the thermal bridges effects for the two analyses walls structures.

Table 4. The heat looses coefficient due to the thermal bridges effects for the exterior wall without thermal insulation

DETAIL: Exterior wall - basement floor without thermal insulation				
Surface	Temperature			
	[°C]			
interior	20			
exterior	0			
ground	10			
Real heat looses	U Value	Surface	ΔT	U_{reg}
	[W/(m2K)]	[m²]	[K]	[W/m]
Exterior wall (Ureg.)	0.148	1	20	2.970
Floor	0.219	1	10	2.129
			Sum:	5.159
Real value for heat looses	Heat flux			
	[W/m]			
Heat looses (HEAT 5.0)	15.6777			
Minimal temperature	19.4			

Te=0°C				
			Sum:	15.677
Thermal bridge heat looses coefficient	Thermal bridges coefficient Ψa			
	[W/(mK)]			
$\Psi_{PE,ext}$ = $\Psi_{wall} = \frac{Q_{heat} - Q_{reg,total}}{\Delta T}$	0.526			
Total value for the thermal bridges heat looses coefficient			Ψa:	0.526

In the next tables will be calculated the thermal transmittances for each component surface of the exterior wall with thermal insulation, depending on the component materials (tables 5, 6, and 7).

Table 5. Thermal transmittance calculation for the exterior wall surface in contact with the exterior air

Exterior wall				
	Thermal resistance [m²K/W] interior $1/\alpha_i$	0.13	Thermal conductivity	Thickness d
	exterior $1/\alpha_a$	0.04		[mm]
	Elements 1		λ	
1	Aired concrete		0.090	200
2	Polystyrene expanded		0.035	150
3	Plaster		0.350	20
		U value:	0.148 W/(m²K)	
			Thickness	37.0

Table 6. Thermal transmittance calculation for the floor basement in contact with the ground

Floor in contact with the ground				
	Thermal resistance [m²K/W] interior $1/\alpha_i$	0.00	Thermal conductivity	Thickness d
	exterior $1/\alpha_a$	0.04		[mm]
	Elements1		λ	
1	Aired concrete		0.090	150
2	Concrete		2.300	150
3	Polystyrene expanded		0.035	200
		U value:	0.134 W/(m²K)	
			Thickness	50.0

Table 7. The heat looses coefficient due to the thermal bridges effects for the exterior wall with thermal insulation, polystyrene

DETAIL: Exterior wall – basement floor with thermal insulation				
Surface	Temperature			
	[°C]			
interior	20			
exterior	0			
ground	10			
Real heat looses	U value	Surface	ΔT	U_{reg}
	[W/(m2K)]	[m²]	[K]	[W/m]
Exterior wall (Ureg.)	0.148	1	20	2.970
Floor	0.134	1	10	1.336
			Sum:	4.305
Real value for heat looses	Heat flux			
	[W/m]			
Heat looses (HEAT 5.0)	5.0359			
Minimal temperature Te=0°C	19.4			
			Sum:	5.0359
Thermal bridge heat looses coefficient	Thermal bridges coefficient Ψa			
	[W/(mK)]			
$\Psi_{PE,ext}$ = $\Psi_{wall} = \frac{Q_{heat} - Q_{reg,total}}{\Delta T}$	0.037			
Total value for the thermal bridges heat looses coefficient			Ψa:	0.037

CONCLUSIONS

Taking into account the comparative analyze of those two walls structures it can be developed the next conclusions:

The inside and limit temperatures are lower for the wall structure that doesn't has a thermal insulation (figure 10) comparing to the wall structure that has thermal insulation on the exterior (figure 13).

Considering the wall structure that has polystyrene insulation in contact with the exterior air, the heat looses coefficient due to the thermal bridges is Ψ_a =0.037 W/mK, comparing with the wall structure that doesn't has thermal insulation Ψ_a=0.526 W/mK.

For the wall structure that doesn't has polystyrene insulation in contact with the exterior air, the thermal transmittance is U=0.148 W/m^{2}K and for the structure in contact with the floor basement is, U=0.219W/m^{2}K.

The wall structure that has polystyrene insulation in contact with the exterior air the thermal transmittance is U=0.148 W/m^{2}K, and for the structure in contact with the floor basement is, U=0.134W/m^{2}K.
The thermal transmittance for the surface of the wall in contact with the exterior air is bigger comparing to the surface in contact with the floor basement because the ground temperature is 10°C and the exterior air only 0°C, and both surfaces had thermal insulation, exterior wall had polystyrene expanded thermal insulation with a thickness of 150 cm comparing to the Floor in contact with the ground with a thickness of 200 cm.
Using the thermal insulation the heat fluxes variations will be lower and also the inside temperatures will grow up, especially if the thermal insulation is correct dimensioned and energetically efficient.

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