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The Influence of The Glazing Area on the Opaque Area, at a Wall having a Window

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Summary

The resistance structure of the building forms linear thermal bridges in the building envelope elements. The intersection of those linear thermal bridges is forming thermal bridges having a spatial geometry. Thermal bridges are zones with the highest thermal permeability and temperatures having minimum values on the surface of the building envelope.

The objective of the paper is to establish in an accurate manner the thermal transmittance of an element of the building envelope and the minimum temperatures that arise on the surface of the building envelope, taking into consideration the presence of the thermal spatial bridges formed at the intersection of the linear thermal bridges.

KEYWORDS: Energy economics, Mathematical modelling, Simulation, Heat transfer, Dynamic modelling.

1. INTRODUCTION

The continuous rise of the energy price for heating the dwelling houses is a permanent concern of designers, researchers, and specialists in the field of thermal insulating of buildings and for energy savings during their exploitation life.

For a better knowing of the real phenomenon of the flows that are passing through the elements of the building envelope, the determination of the spatial temperature fields is imposed, with the help of some specific calculus programs based on which, the energetic performance of the building is determined. Since 1978 our research collective is interested and preoccupied in elaborating those types of programs. Using these types of programs, energetic efficient constructive solutions were elaborated for the elements of the building envelope used for constructing new buildings. For the existing fund of buildings, the elaborated calculus programs were used for determining the energetic performances, with the purpose of energetic certifying of the building and for the analyses of the energetic solutions of energetic rehabilitation.

From the package of thermal - energetic calculus programs of buildings, the most used is the „CIMPSPAT" program that establishes the temperature spatial field in steady state regime, for elements having a complex formation.

From the many studied cases by our research collective, the paper presents just a part of the studies made. The study refers to 2 types of walls, an opaque wall and a wall having a window, non-insulated and insulated with expanded polystyrene in 4 variants of insulating, respectively 5 cm, 10 cm, 15 cm and 20 cm. The thermal insulation of the building on the exterior surface of the wall is turned on the embrasures of the window hole, up to the window frame with a thickness of 4m.

We limited in presenting the results for the energetic behavior of the 2 types of walls, without approaching in this paper the complex problem of superficial temperatures and the risk of condense, for avoiding the mould appearance

2. METHODOLOGY AND RESULTS

2.1. The work method

The thermal flows and the superficial temperatures are determined based on the spatial temperature fields established on a 3D spatial geometric model, in accordance with the methodology presented in Norm *EN ISO 10211/1:2005 "Thermal bridges in building construction-Calculation of heat flows and surface temperatures-Part 1:General Methods"*, using calculus methods of class A. For the calculus of the thermal flows and the superficial temperatures the used calculus methods are similar, but are not identical implying different contour conditions.

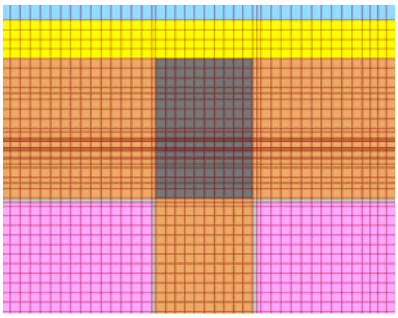
For determining the thermal flows and the superficial temperatures the calculus program CIMPSPAT 2008 variant (initial variant 1980), is used. The program establishes the spatial temperature field in steady state regime for elements having complex formation, using the high preciseness method of the thermal balance, in each node of the calculus network. The number of the digitization network on the 3 directions, the number of the materials having different physical characteristics and the number for conditions to limit is unlimited. The equations number of the energy balance is influenced by the computer capacity. The programming language used for the calculus program has developed from Fortran to Pascal and up to Delphi 7, having inserted the calculus modules in C++ language.

Based on the temperature field determined in the calculus network nodes and the thermal flows in the nodes from the surfaces of the element are determined. The mathematical modeling of the spatial heat transfer phenomena in stationary thermal regime is given by the equations with second order partial derivatives with limit conditions, having the next formula:

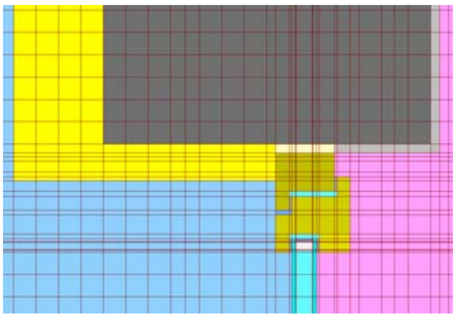
$$\frac{\partial}{\partial x}\left[\lambda(x,y,z)\cdot\frac{\partial\theta(x,y,z)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\lambda(x,y,z)\cdot\frac{\partial\theta(x,y,z)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\lambda(x,y,z)\cdot\frac{\partial\theta(x,y,z)}{\partial z}\right]=0$$

(1)

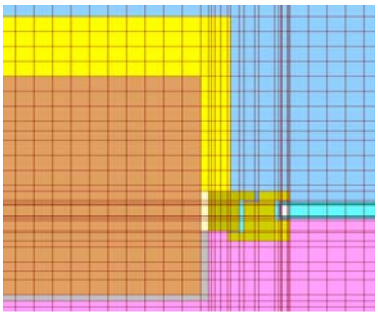
The iterative calculus of the equations system obtained by writing the energy balance in the network nodes is considered finalized, when the flows on the interior and exterior surface are in equilibrium, which means that the sum of the flows that enter and exit through the surfaces of the elements is lower than a given precision. Usually the precision is ε=0.001 W for the current construction elements and a higher precision for the envelope elements that contain thermal bridges with higher thermal conductivities (metallic elements).



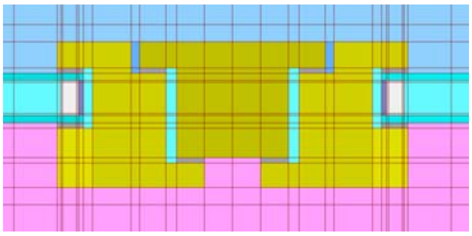
a.) the intersection of walls



b.) the window under the lintel



c.) window – wall joining



d.) the sash of the window

Figure 1. Details for the spatial network of digitization

The spatial geometric model, contained between the cutting planes was divided with the help of some sectional planes to form the orthogonal temperature field

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design network. The calculus network placed automatically by the calculus program having steps covering between 10 and maximum 25 mm on all directions, taking into consideration the stipulations of 5th chapter “The Building Modeling” from the EN ISO 10211-1:1995 norm. For an accurate evaluation of the heat losses in the room, the cutting planes were placed at about 1 meter in the interior of the room and about 50 centimeters in the opposite rooms.

Because of the limited space, in the paper is presented the thermal performance of one of the frequent solutions used in making the buildings in Romania. The solution is a full brick masonry wall of 36,5 cm thick, presented in two constructive solutions of realization (without window and with window), before and after thermal rehabilitation. The climatic conditions were considered the ones from the III^{rd} climatic zone, were our city lies, which mean an exterior air temperature of -18^{o}C.

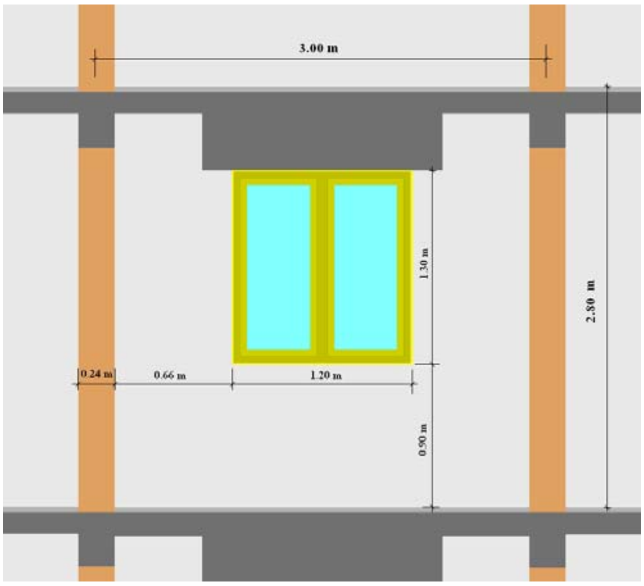

Figure 2. The geometric dimensions of the wall having a window

The analyzed element has the following geometrical dimensions:

- the thickness of the standard solid brick masonry is d=36.5 cm.
- the flooring thickness is 14 cm.
- the wall plaster layer is 1 cm thick inside and 2 cm thick outside.
- The additional thermal insulation on the external side of the wall was taken for four variants of thicknesses: 5 cm, 10 cm, 15 cm, 20 cm. Over the thermal

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insulation material a plaster of 5 mm reinforced with glass fiber net, was applied.

The opaque wall, having an interaxis dimension of 3 m and a height of 2,80 m, has a total surface of 8,40 m^2. For the variant of the wall having a window, the total surface of the wall is of 8,40 m^2, from which the opaque surface is of 6,89 m^2 and the surface of the window of 1,51 m^2. The dimensions of the window hole are 1,20 x 1,30. For this type of window placed in the hole with the named dimensions, using the calculus relation (1) from the Norm EN ISO 10077/1:2000, the thermal transmittance of the window will be U_{wn}=1,676 W/m^2K.

For the thermal characteristics of the glazing surface, the calculus thermal conductivities λ_c [W/(m·K)] and the normal emissivity coefficients of the surfaces ε_n of the materials used for making the window, were those in Annex D of Norm 10077/2:2003. The equivalent thermal conductivity λ_{ech} of the air from the cavities of the window framework, are determined by taking into consideration the thermal flow through conduction, convection and radiation, depending on the cavity geometry and of the emittance characteristics of the surfaces that delimitates it. For the non-ventilated cavities, few ventilated and ventilated the procedure from point 6 of the norm 10077/2:2003 was taken into consideration. The next values from the norm were taken into consideration: $U_{g,n}$=1.3 W/(m^2·K), $U_{f,n}$=1.36 W/(m^2·K), the bi-dimensional thermal coupling coefficient L^{2D}_n=0.481 W/(m·K) and the linear thermal transfer coefficient of the aluminum element of spacing ψ_n=0.084 W/(m·K)

The design heat conductivities of the building materials used for our study are as follows:

- standard solid brick masonry, of ρ = 1800 kg/m^3 and λ = 0.80 W/(m·K);
- cement and lime mortar plaster, of ρ = 1700 kg/m^3 and λ = 0.87 W/(m·K);
- reinforced concrete of ρ = 2500 kg/m^3 and λ = 2.00 W/(m·K);
- thermo-insulating material cellular polystyrene of ρ = 20 kg/m^3 and λ = 0.044 W/(m·K)

2.2. Analysis of the obtained results

The results obtained by using the calculus program, are presented under numerical and graphical form, respectively under isothermal shapes. The results were obtained from the study made on two constructive solutions of walls, respectively a full wall and the wall having a window.

In the case of the full wall, from comparing the obtained results in the four solutions of wall thermal insulating, with the results obtained in the case on non-insulated wall, a decrease of the heat flow is observed, respectively of the thermal transmittance from 31%- for the case of 5 cm insulation, to 10 %- in the case of 20cm insulation.

Table 1. Numerical results for the opaque wall

Total for the element	The insulation degree				
	Non insulated	Insulated			
		5 cm	10 cm	15 cm	20 cm
Φ_o [W]	644.66	195.90	115.09	81.31	63.01
R_o [m^2K/W]	0.495	1.629	2.773	3.926	5.066
U_o [W/m^2K]	2.019	0.614	0.361	0.255	0.197
%	100	30	18	13	10

For the wall having a window hole is observed that the distribution of the total heat flow from the wall between the opaque area and the glazing area for the opaque area, will decrease along with the increase of the protection degree from 82%- for the case of the non insulated wall to 20%- for the case of the insulated wall with 20 cm. For the glazing area the total heat flow rises from 18 % - in the case of the insulated wall up to 60 % - the case of the non insulated wall. The thermal transmittance will reduce along with the rise of the thermal insulation degree, form the insulated case with 5 cm up to the insulated case with 20 cm.

Comparing the values for the thermal transmittance of this type of window, determined based on the calculus relation from the norm 10077/ 1,2, with the values of the thermal transmittance determined based on the spatial calculus of the temperature field, differences are observed up to 41 % in the case of the non insulated wall, and of 28- 29% in the four variants of rehabilitation.

The calculus relations foreseen in the 10077/ 1,2 norm are not taking into consideration the areas with high thermal permeabilities of the window, represented by the punctual thermal bridges which are formed at the intersection of the linear thermal bridges, represented by frames and spacers at the corners of the window and at the contact between the sash and the frame of the window. This can be observed in the way the isothermal surfaces are arranged on the surface of the glass and on the surface of the window frame as seen in figure number 4, for the case of the insulated wall.

Table 2 . Numerical results for the wall having a window hole

		The insulation degree				
		Non insulated	Insulated			
			5 cm	10 cm	15 cm	20 cm
The opaque area of the wall	**Φ_o [W]**	609.25	174.40	123.80	97.45	83.09
	Φ_o/ Φ_{tot} [%]	82	58	50	44	40
	R_o [(m^{2}K)/W]	0.429	1.501	2.115	2.687	3.150
	U_o [W/ (m^{2}K)]	2.327	0.666	0.473	0.372	0.317
The glazing area	**Φ_v/ Φ_{tot} [W]**	136.09	124.44	123.74	123.04	122.95
	%	18	42	49	56	60
	R_v [(m^{2}K)/W]	0.422	0.461	0.464	0.467	0.467
	U_w [W/(m^{2}K)]	2.370	2.168	2.155	2.144	2.142
	U_w/U_n [%]	1.41	1.29	1.29	1.28	1.28
Total for the element	**Φ_T [W]**	745.34	298.84	247.54	220.48	206.04
	%	100	100	100	100	100
	R_T [(m^{2}K)/W]	0.428	1.068	1.289	1.448	1.549
	U_T [W/ (m^{2}K)]	2.335	0.936	0.776	0.691	0.646
	%	100	40	33	30	28

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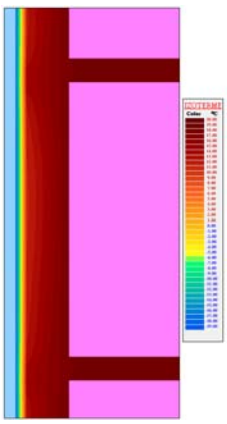
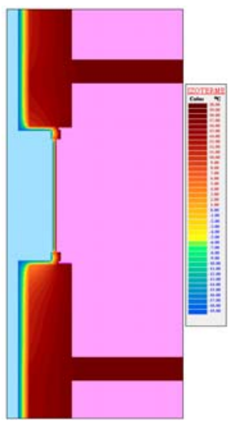
If the results obtained for the full wall are compared with the results obtained for the wall having a window, a rise of the thermal transmittance is observed because of the presence of the window, with 16% for the case of non insulated wall and 228% for the case of insulated wall with 20 cm (table 3).

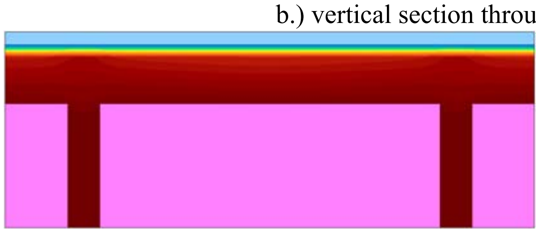
Table 3 . Comparative numerical results for the full wall- wall having a window hole

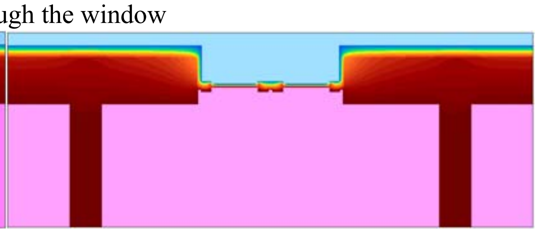
Total for the element	**The insulation degree**				
	Non insulated	**Insulated**			
		5 cm	**10 cm**	**15 cm**	**20 cm**
U_0 [W/(m^{2}K)]	2.019	0.614	0.361	0.255	0.197
U_T [W/ (m^{2}K)]	2.335	0.936	0.776	0.691	0.646
$(U_T- U_0)/ U_0$ [%]	16	52	115	171	228



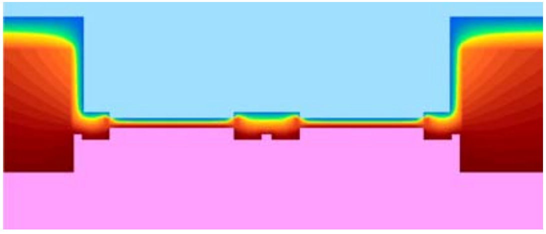


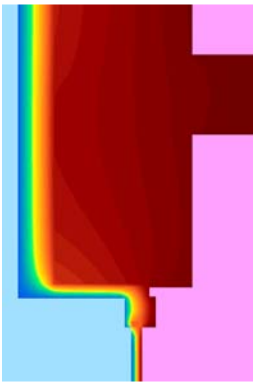
a.) vertical section - full wall
b.) vertical section through the window





c.) horizontal section - full wall d.) horizontal section through the window





e.) detail for the glazing area in horizontal and vertical section

Figure 3. Graphical results (isothermal curves)

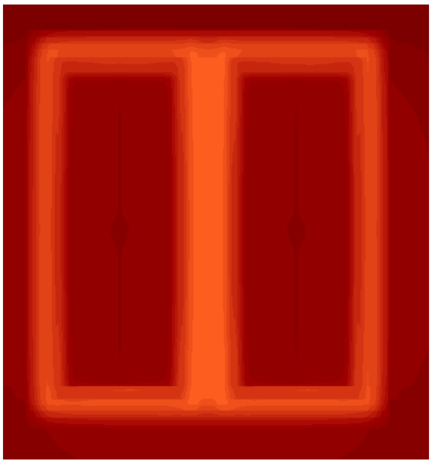


Figure 4. The disposal of the isothermal curves on the frame and the surface of the window glass

3. CONCLUSIONS

From the researches made by our research collective and from the results presented in the paper, the minimum thickness for the thermal insulation for the buildings placed in Romania is of 10 cm thick, equivalent for polystyrene. If the aim is to place the buildings in a superior energetic class, the thickness of the thermal insulation layer has to be of minimum 15 cm thick, equivalent for polystyrene, thickness of the thermal insulation layer that started to be used in the current practice of thermal rehabilitation of the existing buildings in our town.

Figure 5. Building from Cluj- Napoca town in the process of rehabilitation with 15 cm of polystyrene EPS

The calculus program is useful for the accurate evaluation of the heat losses through the elements of the building envelope, for the accurate determination of the necessary heat for the building and for the correct dimensioning of the installations for heating and ventilating a building. The calculus program "CIMPSPAT" represents a valuable instrument for establishing the energetic performances of the envelope elements for the existing buildings in real conditions of exploitation and for designing new types of elements for the building envelope with direct and favorable effects on energy economics in building exploitation and for reducing the pollution emissions in the atmosphere.

The program is easy to use because of its libraries, offering accurate results in a useful time.

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