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THE THERMAL PERFORMANCE OF THE BUILDING ENVELOPE ELEMENTS HAVING GLAZING SURFACES

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ABSTRACT

A good designing of the building represents an important factor for the energy economics. The windows represent one of the important elements in the designing of a building envelope. The window's thermal performances have also a strong influence on the thermal performance of the opaque area of the wall.

This fact imposed knowing the way of real interaction, of co-operation and of mutual influence of the characteristics between the two components of the wall of the building envelope, the opaque and the glazing area.

This mutual inter conditioning is usually favourable for the window behaviour and very unfavourable for the opaque area of the wall where the window is placed.

INTRODUCTION

The study was imposed because of the finding that in practice, establishing the energetic consumption for buildings with the help of the thermal transmittances considered independently for walls and for the joinery, has significant differences in the real behaviour of the wall having a window.

The studies made by our research collective refer to the windows having wood, PVC and aluminium frame, placed in walls built with full or hollow bricks of burned clay, or built with ACB, or walls built with diaphragms of reinforced concrete and big prefabricated panels. The glazing surfaces used in the studies were the one met nowadays on the market.

For an accurate evaluation of the heat losses through the walls foreseen with windows, rooms having diverse lengths, inter-axis openings and heights, in various combinations of wall types with diverse types of frames and of glazing surfaces, had been considered.

THE GEOMETRICAL MODEL

From the numerous studies made, because of the limited space we will present the research results obtained for a room of a typical building in Romania. The structure is made of burned clay full bricks masonry of 36,5 cm thickness, having a height level of 2,70 m, room length of 3,30 m and the room width of 3,00 m.

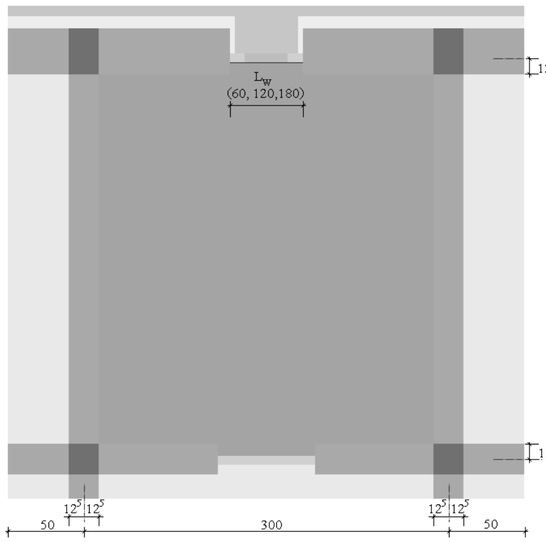

Figure 1 The horizontal section

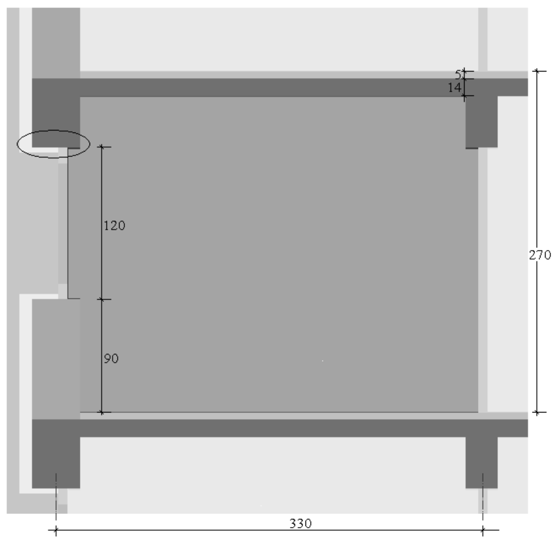

Figure 2 The vertical section

In the wall having a 3,00m length a thermopan window joinery having a PVC frame was foreseen.

The vitreous surface is a double glazed window of 24 mm, structure of 4 -16- 4, filled with Krypton and having a face of the glass coated with an emissivity equal to 0.05 resulting a thermal transmittance U_g=1.1. Another study was made on a triple glazed window of 36 mm, structure of 4 -12- 4- 12- 4, with 2 coated surfaces having an emissivity equal to 0.05, filled with Krypton and U_g=0.5

In the paper are presented the results obtained for windows having a mobile sash with the hole dimension of 1,20x0,60, with 2 mobile sashes with the hole dimension of 1,20x1,20, and with 3 mobile sashes with the hole dimension of 1,80x1,20 (see fig.3).

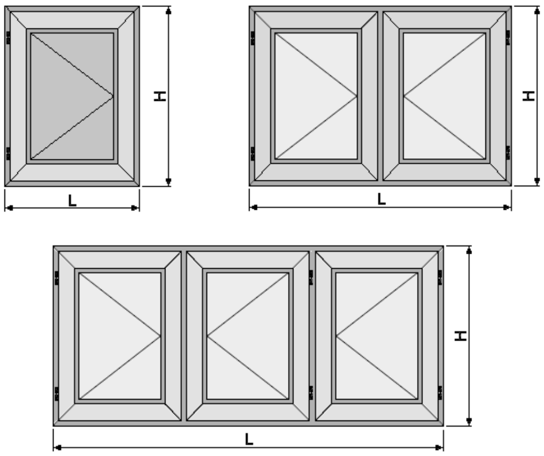

Figure 3 Studied types of windows

PRESENTATION OF THE CALCULUS PROGRAMS

Calculus programs existing in the library of our research collective, elaborated in the past 30 years of activity in the field, were used for determining the energetic performances of the glazing, frame, opaque area of the wall and of the ensemble window-wall,

The calculus program „ SPACIAL GLAZING" was used for determining the thermal performance of the ensemble window-wall. The program takes into account the collaboration between the window and the wall where it is placed, using a spatial analysis (3D). The calculus represents an important step in the thermal-technical calculus of the building elements having complex formation, because it goes from the 2D approach of the calculus to the 3D approach of the calculus. The program is continuously updating by taking into account the stipulations from the international and European standards in the field.

With the help of the program the next were determine: the spatial energetic performance of the glazing U_g, of the frame U_f, and based on those two, the performance of the window U'_w. Using these results, the energetic performance of the opaque area of the wall U' and of the ensemble window-wall U'_{av} (the average value), was determined.

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. The number of the material types that can be used in the program for describing the geometrical model and the contour conditions is unlimited. The program contains a library that includes various constructive formations for walls, various types of frames, of glasses, of filling gases and of spacers.

The program is based on the mathematical modelling for the heat transfer in spatial thermal stationary regime such as:

$$\frac{\partial}{\partial x}\left[\lambda(x,y,z)\cdot\frac{\partial T(x,y,z)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\lambda(x,y,z)\cdot\frac{\partial T(x,y,z)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\lambda(x,y,z)\cdot\frac{\partial T(x,y,z)}{\partial z}\right]=\mathbf{0}$$
(1)

For resolving the equation, the numerical calculus method of high accuracy of the heat balance equilibrium in each node of the spatial discretization network foreseen in the EN ISO 10211-1:1995, Annex A, was used. The validation procedure foreseen in the Annex was used.

The calculus program does the discretization of the spatial geometrical model automatically, having as result the spatial discretization network. The error estimator generates the necessity of extending the subdivision degree of the discretization calculus network The program does this automatically until the next condition is satisfied: between the flows on the interior and exterior surfaces of the ensemble, window-wall a difference lower than 0.01W must exist. In each node of the calculus spatial network differences under 0.000001W must be obtained, condition superior to the one mentioned in the EN ISO 10211-1:1995, point A.2.e.

When a wall having a window is studied, the program generates about 400-500 thousands nodes, an in the case of simultaneously analyse of the windows placed on the façade of the building, the program generates from 2 up to 6 million nodes. (that depends on the computer memory).

The initial variant of the program from 1980, took part at a national validation test of the numerical results with the experimental ones obtained at the hygrothermal testing station from Iasi, for various constructive solutions types with windows.

These programs are similar to any other calculus programs that use spatial temperature fields, the results are identical because of the system of equations for the energetic balance that are written in the nodes of the calculus network, having unique solutions, indifferent of the calculus program type.

WORK METHOD

The discretization of the geometrical model was made with steps covering 0.1 to 2 mm on all directions. In figure 4 a detail of the discretization network profile is presented.

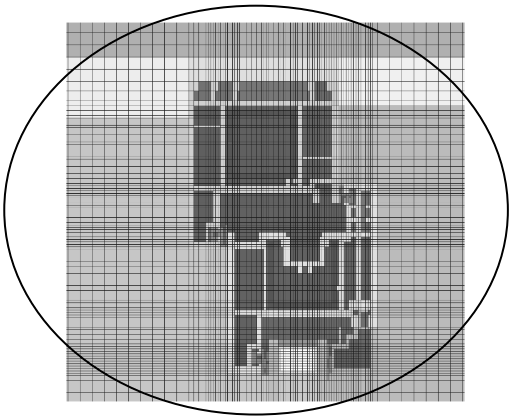

Figure 4 Discretization detail

The design heat characteristics of the building materials used for our study were those taken from the European standards regarding the energy performance of buildings. The contour conditions for the window, regarding the superficial resistances and the temperatures of the exterior and interior medium, were the ones taken in accordance with the stipulations from the norm EN ISO 10077-2:2003.

The following conventional temperatures were used for the purpose of this study: +20^{o}C inside, and -18^{o}C outside (specific for the 3rd climatic zone in Romania).

The energetic performances of the window were determined in 2 comparative ways:

1.) Based on the calculus relations for U_{wn} foreseen in the European standard EN ISO 10077-1:2002:

$$U_{wn} = \frac{A_g \cdot U_g + A_f \cdot U_f + I_g \cdot \psi_g}{A_g + A_f} \qquad (2)$$

where: U_g thermal transmittance of the vitreous area

U_f thermal transmittance of the frame

ψ_g linear thermal transmittance resulted from the combined thermal effects of the vitreous area, the spacer and the frame.

A_g vitreous surface area

A_f frame area

l_g perimeter of the vitreous area

The relation does not take into consideration the next issues :

- the heat losses that take place at the intersection zones of the frame and the aluminium spacer, zones of intensified thermal flow namely the four corners of the window.
- the co-operation between the window and the wall where it is placed.

The method takes into consideration the hypothesis that the window is delimited on the contour by adiabatic cutting planes.

2.) With the help of the spatial calculus program „SPATIAL GLAZING" presented before, the thermal performances were determined in the next way:

1sthyphotesis: the window is delimited on the contour by adiabatic cutting planes and therefore U_{ws} is determined;

2ndhyphotesis: the co-operation between the window and the wall is taken into consideration and therefore U'_w is determined.

THE OBTAINED RESULTS

The results were obtained for the case of the wall with a window, for the three dimensional types of windows presented before.

For the vitreous part, taking into consideration the stipulations from the EN ISO 10077-2:2003 the next were obtained:

- the thermal transmittance of the PVC frame resulted: Uf=1,25 W/m2.K ;
- the linear thermal transmittance coefficients were obtained at the joint of the vitreous area with the frame, ψ:
  - the case of double glazing, the value obtained was 0.028;
  - the case of triple glazing, the value obtained was 0.020.

Using the two calculus methods presented before, the next results were obtained for the three dimensional types of windows:

1.) Using the method from the standard:

a.) for the double glazed window:
- case of one sash : U_{wn}=1,376 W/(m^2·K);
- case of two sashes : U_{wn}=1,375 W/(m^2·K);
- case of three sashes : U_{wn}=1,374 W/(m^2·K).

b.) for the triple glazed window:
- case of one sash : U_{wn}=1,021 W/(m^2·K);
- case of two sashes : U_{wn}=0,999 W/(m^2·K);
- case of three sashes : U_{wn}=0,991 W/(m^2·K).

2.) Using the spatial calculus program „SPATIAL GLAZING", the next values were obtained:

a.) for the double glazed window:
- case of one sash: U_{ws}=1,631 W/(m^2·K);
- case of two sashes: U_{ws}=1,603 W/(m^2·K);
- case of three sashes: U_{ws}=1,595 W/(m^2·K).

b.) for the triple glazed window:
- case of one sash: U_{ws}=1,183 W/(m^2·K);
- case of two sashes: U_{ws}=1,144 W/(m^2·K);
- case of three sashes: U_{ws}=1,128 W/(m^2·K).

Higher values of the thermal transmittance obtained using the calculus spatial program are due to the fact that the presence of the thermal bridges existing at the intersection zones of the frame and the aluminium spacer, are taken into consideration.

From the many studied cases the results obtained for the entire ensemble window-wall, using double and triple glazed windows and the wall presented before, are presented. The results are given as it follows: in table 1 for the wall having the window of

0,60x1,20m, in table 2 for the wall having the window of 1,20x1,20m, and in table 3 for the wall having the window of 1,80x1,20m.
The tables contain data for the next insulating hypothesis at the exterior face of the wall: non insulated, insulated with 5 cm, insulated with 10 cm, insulated with 15 cm, insulated with 20 cm. All these are cases frequently met at the buildings from Romania. For each insulating case of the wall, the turning of the insulation from the wall on the frame bolt in given for 5 variants of thicknesses; 0 cm, 1 cm, 2 cm, 3 cm, 4 cm.
The table contains for all the variants presented, the values of the thermal transmittance, first for the wall without a window, and second for the case of the walls having a window, the values of the thermal transmittaces for the opaque area, vitreous area and the medium values for the ensemble wall opaque + glazing.
For the opaque wall the next values were determined: the thermal transmittance in the current field U_c and the corrected thermal transmittance U'. For the wall having a window the next values were determined: the thermal transmittance of the opaque area U_o, the thermal transmittance of the glazing area U'_w and the thermal transmittance of the ensemble window- wall U'_{av}. The values of these transmittances are compared and presented in tables by percentages.

THE RESULTS ANALYSIS

The results obtained for the opaque area of the wall, for the glazing area and for the ensemble glazing-opaque.
b.) The thermal transmittance obtained in the opaque area of the wall having a window compared with the one obtained for an opaque wall without a window, is very much increased. The difference is reduced for windows having smaller surfaces with a percentage between 10,1% and 241,7%, and higher for windows having bigger surfaces with a percentage between 25,1% and 484,9%. For each type of window, the differences decrease with the increase of the jioning of the thermal insulation. For the same thickness of the jioned thermal insulation, the differences increase with the increase of the thermal insulation thickness on the exterior walls.
The analyzed differences for the double-glazing are the same with insignificant differences for the triple glazing. The findings presented for the opaque area of the wall having a window (U_o), are the same for the average thermal transmittance U'_{av} of the ensemble window-wall that has for the 0,60x1,20m window values between 7,3% and 281,9%, and for the bigger window values between 12,1% and 535,2%.

b.) The analyse of the obtained results for the glazing area of the wall, reveals higher values for the thermal transmittance in the case of small dimensions of windows, and reduced values of the thermal transmittance in the case of big dimensions of windows.
The values of these thermal transmittances are influenced mainly by the thickness of the thermal insulation that is turned from the wall on the frame bolt, having higher values when the insulation is not turned on the frame bolt and lower values when the jioning insulation has a thickness of 4 cm. For the same thickness in jioning, the thickness of the thermal insulation on the exterior wall, influences the values of the thermal transmittance in a limited way (at the second decimal place).In practice, the value is constant no matter the thickness of the thermal insulation on the wall.
Comparing the values of the thermal transmittances of windows for all the 3 dimensional variants of realisation, is observed that the values are higher than the ones calculated according to the calculus relations from the European standard EN ISO 10077-1:2002. The exception is met for the case when the thickness of the thermal insulating layer for the jioning is higher than 3 cm and the thickness of the thermal insulating from the exterior walls over 10 cm at the 0,60x1,20m window, and also for the case when the thickness of the thermal insulating layer for the jioning is 4 cm and the thickness of the thermal insulating from the exterior walls over 10 cm at the 1,20x1,20m window.
In the case of the spatial calculus in the hypothesis of adiabatic cutting planes (U_{ws}), is observed that the obtained values for the thermal transmittance are lower compared to the ones obtained in the hypothesis of co-operation of the ensemble window-wall (U'_w). These differences are higher for the windows having smaller surfaces and lowerfor windows having bigger surfaces.
Thus the calculus relation from the European standard EN ISO 10077-1:2002 gives accurate results only for the next cases: for the 0,60x1,20m window when jioning the thermal insulation with more than 3 cm and a thickness of the exterior thermal insulation of more than 10 cm and for the 1,20x1,20m window when jioning the thermal insulation with 4 cm and a thickness of the exterior thermal insulation of more than 10 cm. For the case of 1,80x1,20m window the results are different with less than 1% for the case of jioning the thermal insulation with 4 cm and the exterior thermal insulation thickness of more than 10 cm. From this analysis, it results the dominant effect that the thickness of the jioned thermal insulating layer at the window frame has on the value of the thermal transmittance of the window.

c.) The values of the thermal transmittances of the glazing area from the ensemble window-wall, are lower than in the case of delimiting the window with adiabatic cutting planes, because of the spatial co-

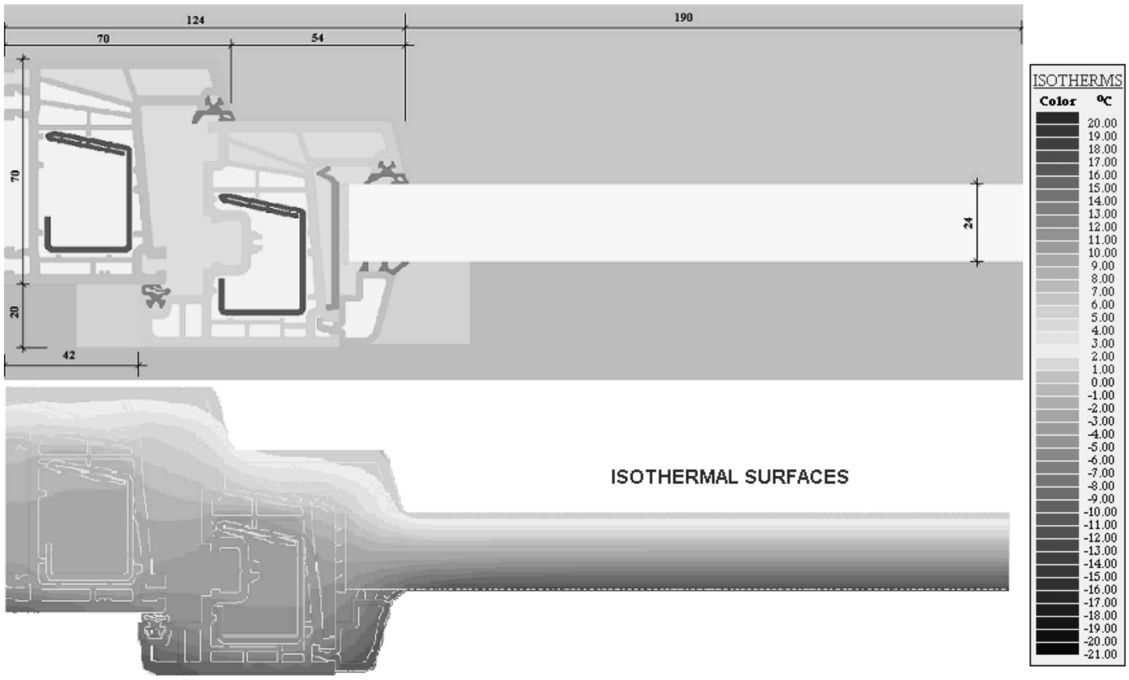

Figure 5 Frame with an thermal insulating panel

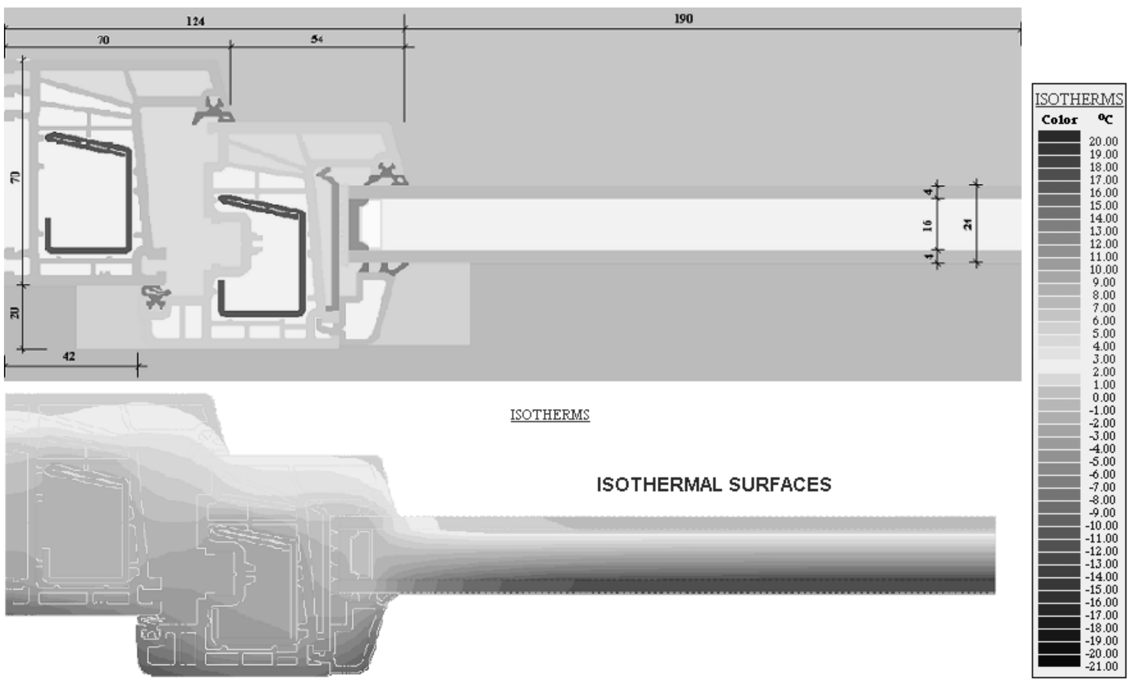

Figure 6 Frame with a window

Table 1

Wall made of full brick masonry of 36,5 cm (Window hole of 60x120 cm)

Polystyrene thickness		Opaque wall	Wall w/ a PVC window(U_f=1.25W/m^{2}K, U_g=1.1W/m^{2}K)							Wall w/ a PVC window(U_f=1.25W/m^{2}K, U_g=0.5W/m^{2}K)						
			Opaque area		Glazing area			Total for the wall		Opaque area		Glazing area			Total for the wall	
Exterior on walls	Jioned	U'	U_o	$(U_o-U')/U'$	U'_w	$(U'_w-U_{ws})/U_{ws}$	$(U'_w-U_{wn})/U_{wn}$	U'_{av}	$(U'_{av}-U')/U'$	U_o	$(U_o-U')/U'$	U'_w	$(U'_w-U_{ws})/U_{ws}$	$(U_w-U_{wn})/U_{wn}$	U'_{av}	$(U'_{av}-U')/U'$
cm	cm	W/m^{2}K	W/m^{2}K	%	W/m^{2}K	%	%	W/m^{2}K	%	W/m^{2}K	%	W/m^{2}K	%	%	W/m^{2}K	%
0	0	2,02	2,23	10,1	1,58	-2,9	15,0	2,17	7,3	2,26	10,1	1,19	0,7	16,6	2,13	5,5
5	0	0,62	1,01	63,7	1,59	-2,4	15,7	1,07	71,9	1,01	63,4	1,20	1,6	17,7	1,03	66,1
10	0	0,36	0,81	122,0	1,59	-2,7	15,3	0,88	140,9	0,81	121,4	1,20	1,1	17,1	0,84	131,0
15	0	0,26	0,72	182,1	1,58	-2,8	15,2	0,80	211,7	0,72	181,3	1,19	0,9	16,9	0,77	197,7
20	0	0,20	0,68	241,7	1,58	-2,9	15,1	0,76	281,9	0,68	240,7	1,19	0,9	16,8	0,72	263,8
5	1	0,62	0,82	32,7	1,50	-8,3	8,6	0,88	42,4	0,82	32,1	1,10	-6,8	7,9	0,84	36,1
10	1	0,36	0,60	63,7	1,48	-9,2	7,6	0,68	85,4	0,59	62,4	1,09	-7,9	6,6	0,64	74,7
15	1	0,26	0,51	96,5	1,48	-9,5	7,3	0,59	130,0	0,50	94,6	1,08	-8,4	6,1	0,55	114,8
20	1	0,20	0,46	128,6	1,47	-9,7	7,0	0,55	174,4	0,45	126,1	1,08	-8,6	5,8	0,51	154,3
5	2	0,62	0,76	23,2	1,43	-12,1	4,1	0,82	32,9	0,76	22,6	1,04	-11,7	2,2	0,79	26,6
10	2	0,36	0,53	45,1	1,42	-13,1	3,0	0,61	66,8	0,52	43,7	1,03	-13,1	0,6	0,57	56,0
15	2	0,26	0,43	68,5	1,41	-13,5	2,5	0,52	102,3	0,43	66,5	1,02	-13,6	0,1	0,48	87,2
20	2	0,20	0,38	92,0	1,41	-13,7	2,3	0,47	137,7	0,38	88,9	1,02	-13,9	-0,2	0,43	118,1
5	3	0,62	0,73	18,4	1,38	-15,4	0,2	0,79	27,6	0,73	17,6	1,00	-15,6	-2,3	0,75	21,5
10	3	0,36	0,49	35,4	1,36	-16,6	-1,2	0,57	56,6	0,49	34,1	0,98	-17,2	-4,2	0,53	46,2
15	3	0,26	0,40	53,7	1,35	-17,0	-1,7	0,48	86,8	0,39	51,8	0,97	-17,8	-4,8	0,44	72,0
20	3	0,20	0,34	72,4	1,35	-17,3	-2,0	0,43	117,1	0,34	69,8	0,97	-18,1	-5,1	0,39	98,0
5	4	0,62	0,71	15,0	1,33	-18,2	-3,1	0,77	23,9	0,71	14,4	0,96	-19,1	-6,3	0,73	17,9
10	4	0,36	0,47	28,6	1,31	-19,5	-4,6	0,54	49,2	0,46	27,5	0,94	-20,9	-8,4	0,51	39,0
15	4	0,26	0,37	43,6	1,30	-20,0	-5,2	0,45	75,9	0,36	42,0	0,93	-21,5	-9,1	0,41	61,5
20	4	0,20	0,32	58,8	1,30	-20,3	-5,5	0,40	102,5	0,31	56,8	0,92	-21,9	-9,5	0,37	83,9

Table 2

Wall made of full brick masonry of 36,5 cm (Window hole of 120x120 cm)

Polystyrene thickness		Opaque wall	Wall w/ a PVC window(U_f=1.25W/m^{2}K, U_g=1.1W/m^{2}K)							Wall w/ a PVC window(U_f=1.25W/m^{2}K, U_g=0.5W/m^{2}K)						
			Opaque area		Glazing area			Total for the wall		Opaque area		Glazing area			Total for the wall	
Exterior on walls	Jioned	U'	U_o	$(U_o-U')/U'$	U'_w	$(U'_w-U_{ws})/U_{ws}$	$(U'_w-U_{wn})/U_{wn}$	U'_{av}	$(U'_{av}-U')/U'$	U_o	$(U_o-U')/U'$	U'_w	$(U'_w-U_{ws})/U_{ws}$	$(U'_w-U_{wn})/U_{wn}$	U'_{av}	$(U'_{av}-U')/U'$
cm	cm	W/m^{2}K	W/m^{2}K	%	W/m^{2}K	%	%	W/m^{2}K	%	W/m^{2}K	%	W/m^{2}K	%	%	W/m^{2}K	%
0	0	2,02	2,36	16,9	1,55	-3,1	13,0	2,22	9,8	2,36	16,9	1,14	-0,3	14,1	2,15	6,1
5	0	0,62	1,21	95,0	1,55	-3,1	13,0	1,27	105,0	1,21	94,7	1,14	-0,3	14,1	1,20	92,7
10	0	0,36	1,02	180,5	1,55	-3,3	12,7	1,11	206,3	1,02	179,7	1,14	-0,6	13,8	1,04	185,4
15	0	0,26	0,95	268,1	1,55	-3,4	12,7	1,05	309,7	0,94	266,9	1,14	-0,8	13,6	0,98	280,2
20	0	0,20	0,91	354,8	1,55	-3,4	12,6	1,02	412,1	0,90	353,3	1,14	-0,8	13,6	0,94	374,4
5	1	0,62	0,93	49,8	1,49	-7,2	8,2	1,03	65,8	0,92	48,7	1,07	-6,1	7,5	0,95	53,1
10	1	0,36	0,71	95,9	1,48	-7,7	7,6	0,85	133,2	0,71	94,0	1,07	-6,8	6,7	0,77	111,5

15	1	0,26	0,63	114,0	1,48	-7,9	7,4	0,78	202,3	0,62	140,9	1,06	-7,1	6,3	0,70	171,6
20	1	0,20	0,58	191,5	1,47	-8,0	7,2	0,74	271,4	0,57	187,9	1,06	-7,2	6,2	0,66	231,7
5	2	0,62	0,84	35,0	1,44	-10,3	4,6	0,94	52,1	0,83	33,9	1,03	-10,2	2,8	0,86	39,5
10	2	0,36	0,61	66,8	1,43	-11,0	3,8	0,75	106,9	0,60	64,8	1,02	-11,2	1,7	0,67	85,2
15	2	0,26	0,52	100,8	1,42	-11,3	3,4	0,68	163,4	0,51	98,1	1,01	-11,5	1,3	0,60	162,7
20	2	0,20	0,47	134,7	1,42	-11,4	3,3	0,64	220,1	0,46	131,2	1,01	-11,7	1,1	0,56	180,4
5	3	0,62	0,79	27,7	1,40	-12,5	2,1	0,90	45,2	0,79	26,6	1,00	-12,8	-0,2	0,82	32,7
10	3	0,36	0,56	52,7	1,39	-13,3	1,1	0,70	93,4	0,55	50,8	0,98	-14,0	-1,5	0,63	72,0
15	3	0,26	0,46	79,4	1,39	-13,6	0,7	0,63	143,6	0,45	76,7	0,98	-14,3	-1,9	0,55	113,2
20	3	0,20	0,41	106,5	1,38	-13,8	0,5	0,58	193,5	0,40	103,0	0,98	-14,6	-2,2	0,51	154,3
5	4	0,62	0,76	22,9	1,38	-13,8	0,4	0,87	40,6	0,76	21,9	0,98	-14,6	-2,2	0,80	28,4
10	4	0,36	0,52	43,1	1,37	-14,8	-0,6	0,67	84,3	0,52	41,5	0,96	-15,7	-3,5	0,59	63,2
15	4	0,26	0,42	65,0	1,36	-15,1	-1,0	0,59	130,0	0,42	62,6	0,96	-16,2	-4,1	0,51	100,0
20	4	0,20	0,37	87,4	1,36	-15,3	-1,2	0,55	175,4	0,37	83,9	0,96	-16,4	-4,3	0,47	136,7

Table 3

Wall made of full brick masonry of 36,5 cm (Window hole of 180x120 cm)

Polystyrene thickness		Opaque wall	**Wall w/ a PVC window(U_f=1.25W/m^{2}K, U_g=1.1W/m^{2}K)**							**Wall w/ a PVC window(U_f=1.25W/m^{2}K, U_g=0.5W/m^{2}K)**						
			Opaque area		Glazing area			Total for the wall		Opaque area		Glazing area			Total for the wall	
Exterior on walls	Jioned	U'	U_o	$\frac{(U_o-U')}{U'}$	U'_w	$\frac{(U'_w-U_{ws})}{U_{ws}}$	$\frac{(U'_w-U_{wn})}{U_{wn}}$	U'_{av}	$\frac{(U'_{av}-U')}{U'}$	U_o	$\frac{(U_o-U')}{U'}$	U'_w	$\frac{(U'_w-U_{ws})}{U_{ws}}$	$\frac{(U'_w-U_{wn})}{U_{wn}}$	U'_{av}	$\frac{(U'_{av}-U')}{U'}$
cm	cm	W/m^{2}K	W/m^{2}K	%	W/m^{2}K	%	%	W/m^{2}K	%	W/m^{2}K	%	W/m^{2}K	%	%	W/m^{2}K	%
0	0	2,02	2,53	25,1	1,54	-3,2	12,4	2,27	12,1	2,53	25,0	1,12	-0,5	13,3	2,15	6,5
5	0	0,62	1,44	131,8	1,54	-3,3	12,3	1,47	136,3	1,43	131,1	1,12	-0,6	13,2	1,35	117,7
10	0	0,36	1,27	248,1	1,54	-3,5	12,1	1,34	268,1	1,26	247,0	1,12	-0,8	12,9	1,23	236,5
15	0	0,26	1,20	366,9	1,54	-3,5	12,0	1,29	401,9	1,20	365,4	1,12	-0,9	12,8	1,18	357,2
20	0	0,20	1,16	484,9	1,54	-3,5	12,0	1,26	535,2	1,16	482,9	1,12	-0,9	12,8	1,15	477,4
5	1	0,62	1,05	68,9	1,47	-7,6	7,3	1,16	87,3	1,04	37,4	1,05	-6,6	6,3	1,04	68,1
10	1	0,36	0,84	131,0	1,47	-8,1	6,7	1,01	176,9	0,83	128,3	1,05	-7,3	5,5	0,89	144,0
15	1	0,26	0,76	195,7	1,46	-8,2	6,5	0,95	168,5	0,75	191,4	1,04	-7,5	5,3	0,83	222,2
20	1	0,20	0,72	260,3	1,46	-8,4	6,4	0,92	360,3	0,71	254,8	1,04	-7,6	5,1	0,80	300,0
5	2	0,62	0,92	49,0	1,44	-9,6	5,0	1,06	71,3	0,91	47,4	1,02	-9,2	3,4	0,94	52,3
10	2	0,36	0,70	92,6	1,43	-10,1	4,4	0,90	146,2	0,69	89,8	1,02	-10,0	2,5	0,78	113,7
15	2	0,26	0,61	138,9	1,43	-10,4	4,1	0,83	223,3	0,60	134,6	1,01	-10,3	2,1	0,71	177,0
20	2	0,20	0,57	185,4	1,43	-10,5	3,9	0,80	300,5	0,56	179,9	1,01	-10,4	2,0	0,68	240,7
5	3	0,62	0,86	38,9	1,41	-11,4	2,9	1,01	62,7	0,85	37,6	1,00	-11,4	0,9	0,89	43,9
10	3	0,36	0,63	73,1	1,40	-12,1	2,1	0,84	129,7	0,62	70,3	0,99	-12,3	-0,2	0,72	97,5
15	3	0,26	0,54	109,7	1,40	-12,3	1,8	0,77	198,8	0,53	105,8	0,98	-12,7	-0,6	0,65	153,3
20	3	0,20	0,49	146,7	1,40	-12,4	1,7	0,73	267,8	0,48	141,7	0,98	-12,9	-0,8	0,61	209,0
5	4	0,62	0,82	32,3	1,40	-12,6	1,5	0,97	57,1	0,81	31,0	0,98	-12,9	-0,8	0,86	38,4
10	4	0,36	0,58	59,9	1,38	-13,3	0,6	0,80	118,7	0,57	57,4	0,97	-13,9	-2,0	0,68	86,8
15	4	0,26	0,49	89,9	1,38	-13,6	0,3	0,72	182,1	0,48	86,4	0,97	-14,3	-2,5	0,61	137,0
20	4	0,20	0,44	120,1	1,38	-13,8	0,1	0,69	246,2	0,43	116,1	0,96	-14,5	-2,7	0,57	187,4

operation phenomena at the intersection of the frame with the wall, and because of the diversion of the heat flows from the glazing area to the opaque area, reducing significantly the thermal performance of the opaque area.

For the ensemble window-opaque the conclusions made for the opaque area of the wall are valid. Compared to a wall without a window, the values of the thermal transmittance are increased with percentages between 7,3% and 281,9% for windows with smaller surfaces and with percentages between 12,1% and 535,2% for windows having bigger surfaces. These percentages are reduced for the case of windows having higher thermal performance.

CONCLUSION

A first conclusion of our research study is that when appreciating the heat losses through walls having windows, is improper to work with the values of the thermal transmittances determined individually for the window and for the opaque area of the wall, without taking into consideration the co-operation between those two.

In current practice when determining the heat necessary for buildings, are usually used glazing and opaque surfaces having their thermal transmittances determined as individual areas. This method gives results that are very far from the real behaviour of the ensemble window- wall.

The only way for a correct approach of the complex phenomena for the ensemble window-wall it can be made by using a calculus program that will permit the spatial analyse of the complex phenomena for the entire ensemble. The approach of the spatial thermal calculus represents an important step in obtaining results near to the real phenomena that takes place in the ensemble window-wall.

Although this is not the purpose of our study, we want to mention the fact that the programs for the non-linear calculus in steady thermal regime, elaborated by our research collective, bring an additional correction to the results obtained in stationary thermal regime. This is because the temperature gradients that are developing in the gas between the glasses and in the cavities of the frame are taken into consideration, and therefore the thermal conductivities of the filling gas and of the air are modified on the height of the window. Because of this phenomenon, the thermal conductivities of the gas and of the air are different on the height of the window, being placed on thicknesses. The existence of this phenomena has consequences on the energetic performance of the window, and implicit on the opaque area of the wall and on the ensemble window-wall.

The benefits of the real thermal transmittance of the ensemble window-wall are:

- the correct assessment of the heat necessary and energy economics in buildings' exploitation, and also in reducing the pollution degree in the atmosphere and implicitly protection of the population health.
- the utilisation, promotion and correct dimensioning of the alternative energy sources like heat pumps, solar traps etc..., in daily exploitation of the buildings which necessitates a correct appreciation of the heat necessary.

The designing of optimal constructive details, energetic efficient for the opaque area and also for the glazing area of the wall, represents a necessity and a trend for nowadays and for the future, in hygrothermal designing of buildings.

REFERENCES

*** EN ISO 13789-99 Thermal performance of buildings – Specific transmission heat loss – Calculation method.

*** EN 13363-2:2005 Dispositifs de protection solaire combines a des vitrages-Calcul du facteur de transmission solaire et lumineuse-Partie 2:Methode de calcul detaillee

*** EN ISO 10211-1:95 Thermal bridges in constructions – Heat flows and surface temperatures – Part 1: General calculation methods.

*** EN ISO 10077-1:2000 Thermal performance of windows, doors and shutters- Calculation of thermal transmittance- Part 1: Simplified method.

*** EN ISO 10077-2:2003 Thermal performance of windows, doors and shutters- Calculation of thermal transmittance- Part 2: General method.

MOGA, L.and MOGA, I. (2008): Applications of the Calculus Program "Spatial Glazing" for Windows, Nordic Symposium on Building Physics NSB 2008, Technical University of Denmark, Copenhagen 16- 18 June 2008, pp.87-95.

MOGA, L.and MOGA, I. (2008): Simulation of the Spatial Thermal Transfer through Windows-Spatial Thermal Transfer Coefficient Calculus-(Extended Abstract), BauSIM 2008, Universitat Kassel, Germany- Kassel 8- 10 September 2008.