

SIMULATION OF THE SPATIAL THERMAL TRANSFER THROUGH WINDOWS- SPATIAL THERMAL TRANSFER COEFFICIENT CALCULUS

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ABSTRACT

The paper presents the researches result concerning the behavior of the glazing surfaces for spatial heat transfer and for the risk of appearance the condense phenomenon on the interior face of the framework, glass and embrasures. The determined heat flows were used for determining the spatial thermal transmission coefficient and also for comparing the coefficient with the values obtained for the same type of window by bi-dimensional method stipulated in the EN ISO 10077-2:2003 norm.

The necessity and opportunity for making the calculus program was imposed by the requirement of explaining the differences in behavior of the window in real conditions of exploitation in comparison with the performances of the window presented by the producer, determined in accordance with the EN ISO 10077-2:2003 norm.

INTRODUCTION

The glazing surfaces represent areas of the building envelope with high permeability. Through those surfaces a percent contained between 15-45 % of the energy needful for heating a building, is lost.

Knowing the complex heat transfer phenomena through the glazing areas of a building has a considerable importance on knowing the energy balance of a building, the energy savings in building exploitation with favorable economic, healthy and environment protection consequences and also for dimensioning the accurate dimensioning of the heating installations.

For studying the heat transfer phenomenon a package of calculus programs named "SPATIAL GLAZING", which was done by the authors, was used.

The calculus program concatenates and develops other calculus programs regarding the elements of the window and of its sun protection, in a modern and complex vision. The main programs are: "SOLAR", "WINDOW", "FRAMEWORK", "WINDOW- WALL".

The calculus program was used for the calculus of the spatial thermal transmission coefficient for windows having wood, PVC and aliminum frameworks.

The expert type calculus program "SPATIAL GLAZING" settles the parameters that define the energetic performance of the glazing surfaces under numerical, chart and graphical shape, isothermal curves and surfaces.

THE MATHEMATICAL MODEL

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:

$$\frac{\partial}{\partial x} \left[\lambda(x, y, z) \cdot \frac{d\theta(x, y, z)}{dx} + \lambda(x, y, z) \cdot \frac{d\theta(x, y, z)}{dy} + \lambda(x, y, z) \cdot \frac{d\theta(x, y, z)}{dz} \right] = 0 \quad (1)$$

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 next conditions were imposed for an accurate resolving of the spatial temperature field:

- the energy balance in each node of the spatial digitization network;
- the flows quality between the ones on the interior and the ones on the exterior face of the window.

THE GEOMETRICAL MODEL

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

The calculus network placed automatically by the calculus program having steps covering between 1 and maximum 10 mm on all directions, taking into consideration the stipulations of 5th chapter "The Building Modelling" 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 centimetres in the apposite rooms , the cutting

planes were placed at about 1 meter in the interior of the room and about 50 centimetres in the opposite rooms.

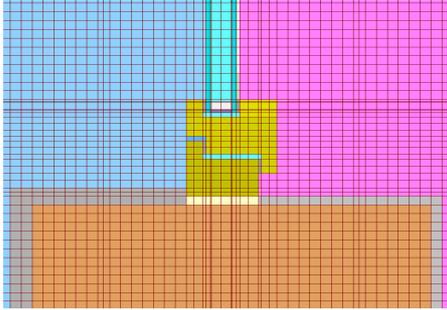


Figure 1 Digitization network on Oyz axis

The entry data, the calorific characteristics of the materials and the contour conditions are introduced in a graphical manner on the spatial geometry of the analysed geometric model.

THE CALCULUS PHYSICAL PROPERTIES

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 thermal technical characteristics of the used building materials were: $\lambda=0,8$ W/m²·K for full brick masonry, $\lambda=0,25$ W/m²·K for AAC, $\lambda=1,74$ W/m²·K for reinforced concrete, $\lambda=0,87$ W/m²·K for interior rendering, $\lambda=0,93$ W/m²·K for exterior rendering, $\lambda=0,93$ W/m²·K for the support layer of the floor, $\lambda=0,44$ W/m²·K for the polystyrene layer belonging to the thermalsystem.

THE COUNTOUR CONDITIONS

For the window the contour conditions regarding the superficial resistances and the temperatures of the exterior and interior medium, were taken the ones in accordance with the stipulations from the norm EN ISO 10077-2:2003.

For the opaque surfaces the contour conditions regarding the superficial heat exchange coefficients

were considered in accordance with the EN ISO 6946:1996 norm. The next values were considered:

- $R_{si}=0,13$ for the interior horizontal thermal flow
- $R_{si}=0,1$ the interior vertical thermal flow having the direction from down to up
- $R_{si}=0,17$ for the interior vertical thermal flows having the direction from up to down
- $R_{se}=0,04$ for the exterior thermal flows.

For representation of the isothermal curves the following temperatures were considered:

- 20°C for the interior air temperature
- -18°C for the exterior air temperature specific for climatic zone were the building is placed.

THE RESULT ANALYSIS

The obtained results using the spatial calculus program “SPATIAL GLAZING” for divers analyzed constructive solutions are presented in comparison with the ones obtained by taking into consideration the stipulation from the EN ISO 10077-2:2003, under numerical and graphical form under curved shapes and isothermal surfaces.

The example presented in the paper refers to the window having the frame profile of wood – figure D4 from the Norm EN ISO 10077-2:2003 and the detail for the aluminium element of spacing between the glass leaves- figure D10.

The notations from the norm were given the “zero” index in order to compare the results with the ones obtained from calculus. The next values from the norm were taken into consideration $U_{g,o}=1.3$ W/m²·K, $U_{r,o}=1.36$ W/m²·K, the bi-dimensional thermal coupling coefficient $L^{2D}_o=0.481$ W/m·K and the linear thermal transfer coefficient of the aluminum element of spacing $\psi_o=0.084$ W/m·K

In order to compare the results obtained with the calculus program for the spatial phenomena and the ones obtained by a manual calculus, the Norm EN ISO 10077-1:2000 was used were the formula for the calculus of the thermal glazing transmittance of the window is given U_w :

$$U_{w,o} = \frac{A_{g,o} \cdot U_{g,o} + A_{f,o} \cdot U_{f,o} + I_{g,o} \cdot \psi_{g,o}}{A_{g,o} + A_{f,o}} \quad (2)$$

where: $U_{g,o}$ is the glazing thermal transmittance

$U_{f,o}$ is the frame thermal transmittance

$\psi_{g,o}$ is the linear thermal transmittance for the combined effects of the glazing, spacing element and the frame.

$A_{g,o}$ is the area of the glass

$A_{f,o}$ is the area of the frame

$l_{g,o}$ is the perimeter of the glass

For the studied window having the dimensions 1,20x1,20 the next values resulted: $A_{g,o}=0.633\text{ m}^2$, $A_{f,o}=0.760\text{ m}^2$, $l_{g,o}=5.360\text{ m}$ resulting the next value for the thermal glazing transmittance of the window: $U_w=1.70\text{ W/m}^2\text{K}$

Our study refers to current constructive solutions met in practice when building residential buildings: full brick masonry made of burned clay having 36,5 centimeters thickness and autoclaved cellular concrete (ACC) masonry of 35 centimeters thickness.

The dimensions interaxis of the walls are of 3.00 meters and the height of the floor of 2.70 meters.

The walls are foreseen with reinforced concrete beams and the room is delimited by reinforced concrete slabs of 15 centimeters thickness that are resting on the masonry through the help of a reinforced concrete ring beam having 25 centimeters thickness. At the holes for the windows a reinforced concrete lintel of 55 centimeters thickness exist that rest on both sides of the hole on 20 centimeters of masonry.

On those types of walls the placing of a window having a wood framework and termopane glass with the holes dimensions 1.20 by 1.20 was analyzed. Five positions of placing the window were considered: (0) at the interior face of the wall, (1) at 10 centimeters distance from the interior face of the wall, (2) in the axis of the wall, (3) at 10 centimeters distance from the exterior face of the wall (4) at the exterior face of the wall.

In tables 1 and 2 are presented in an centralized manner the numerical results obtained for the window having a termopane glass with a wood frame, placed in a wall having a thickness of 36,5 centimeters made of full brick masonry of burned clay.

In tables 3 and 4 are presented in a centralized manner the numerical results obtained for the window having a termopane glass and a wood frame, placed in a wall having a thickness of 35 centimeters made of autoclaved cellular concrete (ACC) masonry.

The isothermal curves for the horizontal and vertical section in the window when the window is placed 10 centimeters from the interior face of the

wall, are presented. The next cases are shown: the frame-wall joint and the frame-frame joint.

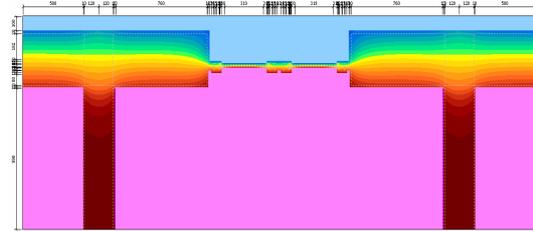


Figure 2 Isothermal curves for different sections through the window

The results are indicating that the energetic qualities of the window frame and of the window ensemble have the most favorable values when the window is placed at the interior face of the masonry. The highest values (unfavorable ones) are when is placed on the exterior face of the masonry, having a varying percent of 3.2%.

The window glass has the same energetic performance qualities no matter where the window is placed in the thickness of the wall, having little variations of 0.1%. The energetic performance of the window frame is much more influenced by the window position varying with about 5% percent.

The total energy loss of the room and of the opaque surface of the wall will rise with a percent of 3.3%.

Comparing the energetic performance values of the window determined based on the calculus relation from the SR EN ISO 10077-1:2000 norm, is observed that for the example presented in the paper the calculated values of the thermal transmittance, have a covering character compared to the calculated ones, having varying percentages from 6.3 up to 9.5%.

The energetic performance of the windowpane presented in SR EN ISO 10077-1:2000 are overestimated with a percent of about 25.8 %. The energetic performance of the window frame is influenced by its position in the thickness of the wall where for the position at the interior is under evaluated with a percent of 3.9% and for the position at the exterior is overestimated.

Analyzing the obtained data for the interior temperature factors on the interior surfaces of the window embrasures, window glass, and window frame is observed that they have the maximum values when the position of the window is at the interior and the minimum ones when the window is placed on the exterior face. So the risk of superficial condense is higher if the joinery is placed in the depth of the window.

Analyzing the data obtained for the case of the (ACC) masonry is observed that the same rules are respected as the ones for the joinery placed in the full brick masonry wall. The total heat loss of the room in the case of the autoclaved cellular concrete (ACC) masonry wall is lower with a percent of about 50% than in the case of the full brick masonry wall. In the same time is observed that for the all heat losses of the room in the case of autoclaved cellular concrete (ACC) masonry wall the heat losses will be greater with a percent varying from 14.5% up to about 20.6%

The effective values for the window thermal transmittance are lower than in this case compared with the ones from the studied case. The behavior of the window glass is the same for the two constructive solutions of walls. The thermal transmittance of the window frame is higher for the case of autoclaved cellular concrete (ACC) masonry wall.

The analyses of the values for the temperature factors for the (ACC) masonry are respecting the same variation law and are showing that for this case the values are better than the ones in the case of full brick masonry wall.

Analyzing the results a first conclusion could be that the energetic performance of the glass, frame, and window as an ensemble is higher when it is placed in walls having lower thermal transmittance.

The values of the temperature factors for the 2 cases are showing that the embrasures, glasses, and frames of the windows have a higher sensitivity at the appearance of the superficial condense phenomenon. For buildings from Romania where for the exterior temperatures the values range between -12°C and -21°C and the relative humidities of the interior air are higher because of the domestic activities that are taking place in abundance every day in residential buildings, the superficial condense phenomena are frequently met at those types of buildings.

Although U_w of the window studied in this example which was calculated with the spatial calculus in comparison with the one from the SR EN ISO 10077-1:2000 norm has a smaller value, the finding is not generally valid.

CONCLUSION

In Romania most of the inhabitants had changed and are changing classical wood joinery that have low air tightness with tightened joinery having termopane glass, placed in walls having high permeabilities, high thermal transmittance and without any control for the air exchange.

The beneficiaries of those joineries are not making comments about the energetic consumptions

through the windows but they comment more about the very frequent phenomena met on the embrasures, glasses, and frames of the window.

The calculus program "SPATIAL GLAZING" becomes helpful in the correct evaluation of the heat losses through the glazing surfaces when establishing the necessary heat for heating up a building, for correct dimensioning of the heating installations, for avoiding the risk of superficial condense, and also gives the choice of optimum constructive solution for the ensemble window-wall.

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