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Modeling of Thermal Transfer Parameters by Transparent Construction Elements

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Abstract **− The article presents a case study on the modeling of heat transfer parameters through transparent construction elements. Conducting experimental studies on the scale of an entire building is very complex, on the one hand due to the size and geometric complexity of the studied objectives and, on the other hand, due to numerous random factors (climatic conditions or how the buildings are operated). In order to be able to carry out a study on the real behavior of the buildings, models are made for them, taking into account the real mode of operation of the installations related to these constructions. The present article consists in making a modeling for a simple exterior window, with a single sheet of glass that separates the interior space of an enclosure (rooms) from the exterior environment. The modeling will be performed both for the case of a building located inside a locality and for the case of the location of the building outside the locality.**

Cuvinte cheie: *transfer termic, clădiri, elemente de construcție transparente, modelare, model*

Keywords: *thermal transfer, buildings, transparent construction elements, modeling, model*

I. INTRODUCTION

Energy consumption due to buildings currently represents, in Romania, approximately 30% of the total energy consumed. This share is constantly increasing, mainly due to air conditioning systems, approaching the level registered in the member countries of the European Union, in which residential and tertiary buildings are assigned a share of energy consumption of approx. 40% of total energy consumption.

Achieving a completely global model that represents a construction in its entirety is practically impossible. As a result, each of the models made in the field of thermo technics of constructions and their related installations represents only certain aspects related primarily to the purpose for which they were made.

For example, the behavior of a building under the action of the wind will be represented differently depending on what is pursued by modeling this phenomenon. So, such a model built for the study of mechanical behavior, will represent the walls of the building by the mechanical characteristics of the materials (modulus of elasticity, limit efforts, etc.) and the wind by the force it exerts on the building. On the other hand, if a model is made for the study of the energetic behavior of the building, the thermophysical characteristics of the materials from which its walls are made (thermal conductivity, specific heat, etc.) and their permeability will be taken into account.

Also, the action of the wind will be represented, in this case, by changing the convective heat exchange coefficient achieved on the outer surface of the building envelope and by the dynamic pressure that influences the air infiltration inside the building through its joints and leaks.

In other words, modeling consists in representing an object or phenomenon in different forms starting from its initial reality, generally using simplifying hypotheses.

The modeling process essentially comprises three main stages [12]:

The construction of the physical model. It is the modeling stage that allows, on the one hand, the analysis of the physical phenomena that intervene in the model, and on the other hand, the adoption of appropriate simplifying hypotheses;

Construction of the mathematical model. In this stage, the physical model is represented, in a certain universal language, so that its degree of complexity is expressed. In the case of very simple physical models there are obvious analytical solutions, and in the case of complicated (complex) models it is necessary to resort to numerical solving;

Construction of the numerical model**.** This stage consists in assigning the values for the parameters of the mathematical model in order to obtain the model equations. At the end of this stage, a set of equations or systems of equations is obtained, in which only the variables of the problem are unknown. Depending on the complexity of the mathematical model, special numerical methods (such as the finite difference method) or the model reduction technique can be used to solve the numerical model, i.e. replacing the complex model with a much smaller model and for which solution is, however, a good approximation of the complete model.

The stages of a modeling process applied in the case of the thermal behavior of constructions (building and related installations) are [5], [12]:

Physical representation that aims at clearly defining the boundaries of the analyzed system (room, apartment or building) and its interactions with external factors (climatic parameters, thermal conditions in neighboring rooms, the action of thermal installations, the action of occupants, etc.);

Mathematical representation is the modeling stage in which the equations characteristic of the analyzed phenomena are written (energy conservation equations and heat and mass transfer equations) and the hypotheses are formulated on the parameters (factors, coefficients, etc.) that intervene. The result of this stage is transcribed in the formulation of the equation or system of equations characteristic of the physical model and also in the clear establishment of the boundary conditions, based on the definition of the boundaries of the model from the previous stage;

Numerical representation is the stage in which the equations or system of equations established in the previous stage is transposed in numerical form, simplified according to the information on parameters and boundary conditions, numerical solving methods and available simulations, etc.

II. HEAT TRANSFER AT GLAZED SURFACES. CONVECTION HEAT TRANSFER MODELLING

The unit surface heat flux q_s is expressed by Newton's cooling law in the form of the product between a property of the system α and the force that generates the process:

$$q_s = \alpha \cdot \left(t_s - t_f\right) \tag{1}$$

Defining in this simplistic way an essentially complicated transfer mechanism gives the convection heat transfer coefficient,α, the property to encompass all the factors that determine the process. Convection heat transfer is influenced by thermodynamic and fluid dynamics factors, because at the interference between fluid and wall the heat exchange is done through the boundary layer. The hydrodynamic factors are:

a) cause of the movement: - the free movement is caused by gravitational forces determined by the temperature gradient, and the forced movement by a potential difference (pressure) created by a pump, fan or blower.

b) Hydrodynamic flow regime: laminar flow regime, Re<2,320; transient flow regime 2.320<Re<10.000; turbulent flow regime, Re>10.000.

The Reynolds criterion is determined by the relation:

$$\mathrm{Re} = \frac{w \cdot d}{\upsilon} \tag{2}$$

where: w - is the velocity of the fluid, [m/s];d - equivalent hydraulic diameter, [m];υ - kinematic viscosity, [m^2 /s].

c) The character of the flow: - subsonic, sonic, supersonic, taking into account the problems specific to each type.

Thermophysical factors:

a) The temperature difference between the wall and the fluid: - for temperature differences $\Delta t>500°C$ the radiant effect is also taken into account in the calculations.

b) Flow behaviour: Newtonian fluids or non-Newtonian fluids.

c) The thermophysical parameters of the fluid: - the density, ρ, the specific heat at constant pressure, c_p, the kinematic viscosity, υ and the coefficient of thermal conductivity, λ, have a great influence on the thermal convection. The average value of the convection coefficient α between a fluid and a wall is obtained from the relation:

$$\alpha = \frac{q}{t_p - t_f} \text{ [W/m}^2\text{·K]} \tag{3}$$

For different hydrodynamic regimes and geometric conditions, the values of the convection coefficientα, are obtained from criterion equations of form: For different hydrodynamic regimes and geometric conditions, the values of the convection coefficientα, are obtained from form criterion equations:

$$Nu = f\left(\mathrm{Re}, Gr, \mathrm{Pr}, ...\right) \tag{4}$$

Determining the values of the similarity criteria for that case, we obtain the numerical value of the Nusselt criterion according to which the average value of the convection coefficient is obtained:

$$\alpha = Nu \cdot \frac{\lambda_f}{l} \tag{5}$$

where: λ_f - thermal conductivity of the fluid, [W / m·K]; l - the characteristic length of the solid wall, [m]. The average value of α along an area S is obtained by the relation:

$$\alpha = \frac{1}{S}\int_S \alpha_x \cdot dS = C \cdot x^{-n} \text{ [W/m}^2\text{·K]} \tag{6}$$

Convection heat transfer and the intervention of this mode of heat exchange in the entire heat exchange from indoor to outdoor air, is based on free convection, being studied from this point of view.

Free convection occurs due to the relatively low level of air speed and is manifested by the flow of hot or cold air along the construction elements. In the case of high air velocities, thermal convection can be studied from the point of view of mixed or even forced convection, but the effects of this modeling would be to obtain high values of heat transferred between the two areas (indoor / outdoor).

As previously stated, the fundamental law of convective heat transfer is known as Newton's Law and allows the calculation of heat flux Q, proportional to the heat exchange surface, S, and the temperature difference between wall temperature and fluid:

$$Q = S \cdot h \cdot \left(T_s - T_f\right) \quad \text{[W]} \tag{7}$$

with:α- thermal convection coefficient, [W / (m^2·K)], which depends on several variables (temperature, velocity, thermal conductivity, viscosity, specific heat, density, etc.) and is calculated for turbulent motion, and laminar with the help of criterion relations.

In order to establish the criteria for calculating the thermal convection coefficient, it is necessary to know the convection type. So:

-for natural convection, the characteristic parameter is the Grashof number, in which case, the modeling of the thermal convection coefficient is done based on the relation:

$$h = C \cdot (Gr \cdot \mathrm{Pr})^n \cdot \frac{\lambda_f}{l} \text{ [W/m}^2\text{·K]} \tag{8}$$

for forced convection, the characteristic parameter is the Reynolds number, in which case, the modeling of the thermal convection coefficient is done based on the relation:

$$h = C \cdot \mathrm{Re}^{0,8} \cdot \mathrm{Pr}^{n} \cdot \frac{\lambda_f}{l} \text{ [W/m}^2\text{·K]} \tag{9}$$

were: $Gr = \frac{g \cdot l^3 \cdot \beta \cdot \Delta T}{\upsilon^2}$ - Grashof criterion; $\mathrm{Pr} = \frac{\upsilon}{a}$ - Prandtl criterion; $\mathrm{Re} = \frac{v \cdot l}{\upsilon}$ - Reynolds criterion; λ_f - thermal conductivity of fluids (in our case air), established from the literature as a function of temperature, [W/(m^2·K)]; l - the characteristic length of the solid element (construction element), [m]; g=9,81 m/s^2 – gravitational acceleration; $\beta = \frac{1}{T_m}$ - isobar coefficient of volume variation, for gases considered ideal, [K^{-1}]; ΔT – solid-fluid temperature difference, [K]; $\upsilon = \frac{\eta}{\rho}$ - the kinematic viscosity of the fluid (in our case, the air), determined as a function of temperature as the ratio between the dynamic viscosity of the fluid, η, and the density of the fluid, ρ; $a = \frac{\lambda}{\rho \cdot c}$ - thermal difussion coefficient, [m^2/s] determined according to the energetic characteristics of the construction element (thermal conductivity of construction material, λ, density of construction material, ρ, specific heat of the material, c);

C, m, n – experimental constants characteristic of each type of movement.

III. Case study for modelling thermal transfer parameters by transparent construction elements

Based on the theoretical aspects regarding the modeling of heat transfer at the level of the envelope elements of a building, the following will establish the parameters that characterize the heat transfer processes at the level of the glazed elements of the tire (windows): the internal coefficient of thermal convection, α_i,[W/(m^2·K)]; the external thermal convection coefficient, α_e,[W/(m^2·K)]; global heat transfer coefficients, k_{FE}, [W/(m^2·K)]; thermal resistance of the glass, R_{FE}, [(m^2·K)/W]; heat flux density at the inner face, q_i, respectively outer face, q_e, of the glass, [W/m^2]; total heat flow transmitted through the window, Q_{FE}, [W];

For this purpose, it is considered a simple exterior window, with a single sheet of glass that separates the interior space of an enclosure (room) from the external environment, having the dimensions represented in figure 1.

From the analysis of the part of the studied room, it is observed that the dimensions of the studied window are: width l_{fer} = 220 cm, height h_{fer} = 300 cm.

In order to evaluate the parameters that characterize the thermal transfer processes at the window level, the following hypotheses are made:

- the outdoor temperature, θ_e, taken into account is represented by the average annual temperature of the cold period, corresponding to climate zone II [2];

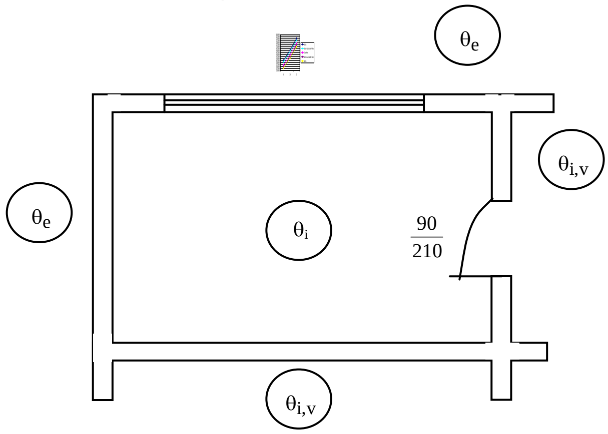

Fig.1. Location of the window in the structure of the building envelope: θe - outside air temperature, [°C]; θ_i - the temperature of the air inside the enclosure considered, [°C], $\theta_{i,v}$ - the air temperature inside the spaces adjacent to the enclosure considered, [°C]

- the air temperature inside the studied room, θ_i, is considered to be the one specific to the thermal comfort established by the norms in force, depending on the destination of the room [7]: $\theta_i = +18^\circ C$; $\theta_i = +20^\circ C$; $\theta_i = +22^\circ C$;

- the intensity of the solar radiation, I_{Tj}, is established for each case, depending on the cardinal orientation "j", of the window and of the locality in which the building is located [2];

- the window is made with ordinary glass, having the absorption coefficient, α_a = 0.10;

- calculation wind speed, established depending on the wind distribution of the localities and the location of the building (inside or outside the locality;

- the air speed inside the room is considered v_i = (0.10 ... 0.15) m/s, considered as a value allowed for comfort conditions in terms of indoor air speed (free convection);

- the window is considered to be: with ordinary glass on the woodwork and wooden frames, in which case the thermal resistance of the window is considered in a first approximation R_0 = 0.19 (m^2·K)/W - FEI [7]; with ordinary glass on the chopping board and metal frames, in which case the thermal resistance of the window is considered in a first approximation R_0 = 0.17 (m^2·K)/W - FEII [7]; with thermal insulation glass on woodwork and wooden frames, in which case the thermal resistance of the window is considered in a first approximation R_0 = 0.33 (m^2·K)/W - FEIII [7]; with thermal insulation glass on the woodwork and metal frames, in which case the thermal resistance of the window is considered in a first approximation R_0 = 0.28 (m^2·K)/W - FEIV [7].

To exemplify the calculation algorithm, the situation was chosen in which the window with the dimensions in figure 1, is with ordinary glass on the woodwork and wooden frames and separates two air zones with temperature inside θ_i = + 20°C, and outside θ_e = + 7.5°C, (v = 4.5 m/s) with S direction orientation and an indoor air speed of 0.1 m/s. The calculation algorithm involves the following steps [6]:

1. Determine the convection coefficient on the inside of the window with the expression:

$$\alpha_i = C \cdot (Gr \cdot \Pr)^n \cdot \frac{\lambda_f}{l} \text{ [W/m}^2\cdot\text{K]} \quad (10)$$

$$Gr = \frac{g \cdot l^3 \cdot \beta \cdot \Delta T}{\upsilon^2} \quad (11)$$

$$l = 2 \cdot l_{fer} + 2 \cdot h_{fer} \text{ [m]} \quad (12)$$

The average thermodynamic temperature is determined as the arithmetic mean between the temperature of the air inside the considered room, and the temperature on the inside of the window, $\theta_{fer,\,i}$.

The temperature on the inside of the window is determined by considering the thermal resistance at the surface of the construction elements (window) as $R_{i,fer}$ = 0.125 m^{2}K/W [7]:

$$\theta_{fer,i} = \theta_i - R_{i,fer} \cdot \frac{\theta_i - \theta_e}{R_0} \text{ [°C]} \quad (13)$$

The thermal conductivity of air, λ_f, is determined by its (air) temperature

As a result, the convection coefficient on the inner face of the glass will be, for a first approximation (figure 1).

2. Determine the convection coefficient on the outer face of the glass with the calculation expression for smooth surfaces:

$$\alpha_e = a + b \cdot v^n \text{ [W/m}^2\cdot\text{K]} \quad (14)$$

3. Calculate the actual temperature recorded on the inner surface of the glass and, if the value obtained is cu1% different from the value obtained by the initial approximation, validate the value of the internal convection coefficient, and determine the other parameters with this value.

$$\theta_{fi} = \theta^* + \frac{\alpha_a \cdot I}{\alpha_i + \alpha_e} [^\circ C] \quad (15)$$

$$\theta^* = \frac{\alpha_i \cdot \theta_i + \alpha_e \cdot \theta_e}{\alpha_i + \alpha_e} \text{ [°C]} \quad (16)$$

The calculation error compared to the initial approximation is:

$\varepsilon_{\theta,fi} = \dfrac{\theta_{fi}^{(1)} - \theta_{fi}^{(2)}}{\theta_{fi}} < \pm 1\% \Rightarrow$ the internal convection coefficient is $\alpha_i = \alpha_i^{(2)} = 3{,}583\ W/(m^2 \cdot K)$.

4. Determine the overall heat transfer coefficient of the glass:

$$k_{FE} = \frac{1}{R_{FE}} = \frac{\alpha_i \cdot \alpha_e}{\alpha_i + \alpha_e} \text{ [W/m}^2\text{K]} \quad (17)$$

5. The total thermal resistance of the window is determined:

$$R_{FE} = \frac{1}{k_{FE}} \text{ [m}^2\text{K/W]} \quad (18)$$

6. Determine the heat flux density on the inside of the window:

$$q_i = k_{FE} \cdot (\theta_i - \theta_e) - \frac{k_{FE} \cdot \alpha_a \cdot I}{\alpha_e} \text{ [W/m}^2\text{]} \quad (19)$$

7. Determine the heat flux density at the outer face of the window:

$$q_e = k_{FE} \cdot (\theta_i - \theta_e) + \frac{k_{FE} \cdot \alpha_a \cdot I}{\alpha_i} \text{ [W/m}^2\text{]} \quad (20)$$

8. The total heat flow transmitted through the window is:

$$Q_{FE} = k_{FE} \cdot S_{FE} \cdot (\theta_i - \theta_e) \text{[W]} \quad (21)$$

For all the situations taken into account in the calculation assumptions mentioned above, the values obtained by modeling the heat transfer at the level of the single window, with a single sheet of glass, variations in the density of heat fluxes on the inside, qi, respectively outside, q_e, glass and total heat flux transmitted through the window, Q_{FE}, depending on the type of window and their geographical orientation being presented, in case the indoor temperature is 18°C, in the diagrams in figures 2 ... 4.

Table 1 shows a centralized calculation example following the modeling of heat transfer at the level of the single window, with a single sheet of glass, for southern orientation, corresponding to climate zone II (θe = + 7.5°C) and air temperature interior θi = 18°C. The variations of the density of the thermal fluxes at the inner face, qi, respectively the outer face, q_e, of the glass and of the total heat flux transmitted through the window, QFE, are determined.

Also, in order to highlight the variations of the parameters that define the heat transfer through the glass envelope elements of a building depending on the variations of the internal air temperature, in the diagrams from figures 5 ... 7, the variations of these parameters are presented, for the case of the window type 1 (it is the most common type of simple window found in constructions in Romania).

TABLE I.
PARAMETERS OF HEAT TRANSFER SIMPLE OUTER WINDOW WITH A SHEET OF GLASS, ORIENTED IN THE CARDINAL DIRECTION SOUTH, CORRESPONDING TO THE CLIMATIC ZONE ($\theta E = +7.5°C$) AND THE TEMPERATURE OF THE INDOOR AIR $\theta I = 18°C$

Crt. no.	Parameter	Location/window type							
		Inside town				Outside town			
		FEI	FEII	FEIII	FEIV	FEI	FEII	FEIII	FEIV
1.	Characteristic window lenght, l, [m]	10,40				10,40			
2.	Temperature on the inner surface of the window for the first approximation, $\theta_{fer}^{(0)}$,[°C]	11,092	10,279	14,023	13,313	11,092	10,279	14,023	13,313
3.	Isobaric coefficient of volume variation, $\beta \cdot 10^{-3}$, [K^{-1}]	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49
4.	The room interrior temperture difference, ΔT, [K]	8,802	8,856	8,795	8,797	9,097	9,153	9,092	9,093
5.	the kinematic viscosity of the fluid (in our case, the air), inside the, $\upsilon \cdot 10^{-6}$, [m^2/s]	14,880	14,880	14,880	14,880	14,880	14,880	14,880	14,880
6.	Grashof criterium, $Gr \cdot 10^{12}$	1,530	1,539	1,529	1,529	1,582	1,592	1,581	1,581
7.	Prandtl citerium for the interior air inside the room, Pr	0,7034	0,7034	0,7034	0,7034	0,7034	0,7034	0,7034	0,7034
8.	Productl $(Gr \cdot Pr) \cdot 10^{12}$	1,076	1,083	1,075	1,075	1,113	1,120	1,112	1,112
9.	Coefficient C	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135
10.	Exponent n	0,333	0,333	0,333	0,333	0,333	0,333	0,333	0,333
11.	Thermal conductivity for the air inside the room, λ_f, [W/m·K]	0,02574	0,02574	0,02574	0,02574	0,02574	0,02574	0,02574	0,02574
12.	Convection coefficient on the inside side of the window, α_i, [$W/m^2 \cdot K$]	3,4208	3,4278	3,4198	3,4201	3,4592	3,4663	3,4585	3,4587
13.	Temperature on the inner surface of the window, θ_{fer}, [°C]	9,1936	9,1959	9,1932	9,1933	8,8996	8,9016	8,8994	8,8995
14.	Convection coefficient on the out side of the window,, α_e, [$W/m^2 \cdot K$]	23,25	23,25	23,25	23,25	29,10	29,10	29,10	29,10
15.	The overall heat transfer coefficient of the glass, k_{FE}, [$W/m^2 \cdot K$]	2,9821	2,9874	2,9813	2,9815	3,0917	3,0974	3,0911	3,0912
16.	Total thermal resistance of the window, R_{FE}, [$m^2 \cdot K/W$]	0,3353	0,3347	0,3354	0,3354	0,3235	0,3229	0,3235	0,3235
17.	Heat flux density on the inside of the win-dow, q_i, [W/m^2]	30,1252	30,1789	30,1173	30,1195	31,4796	31,5378	31,4739	31,4755
18.	Heat flux density on the outside of the window, q_e, [W/m^2]	39,3752	39,4289	39,3673	39,3695	40,7296	40,7878	40,7239	40,7255
19.	The total heat flow transmitted throw the window, Q_{FE}, [W]	206,66	207,03	206,60	206,62	214,25	214,65	214,21	214,22

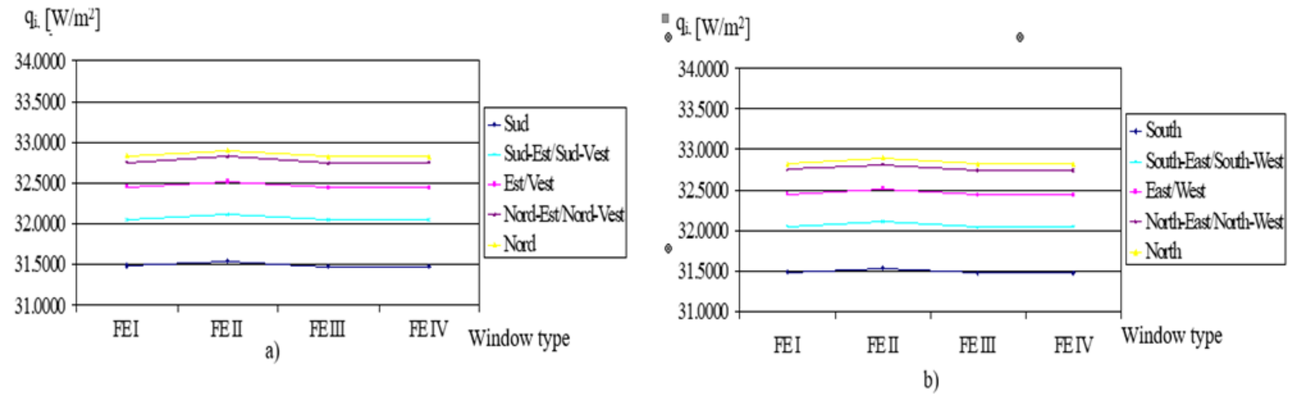

Fig.2.Variations in heat flux density on the inside of the window, depending on its type:
a) location inside the locality; b) location outside the locality.

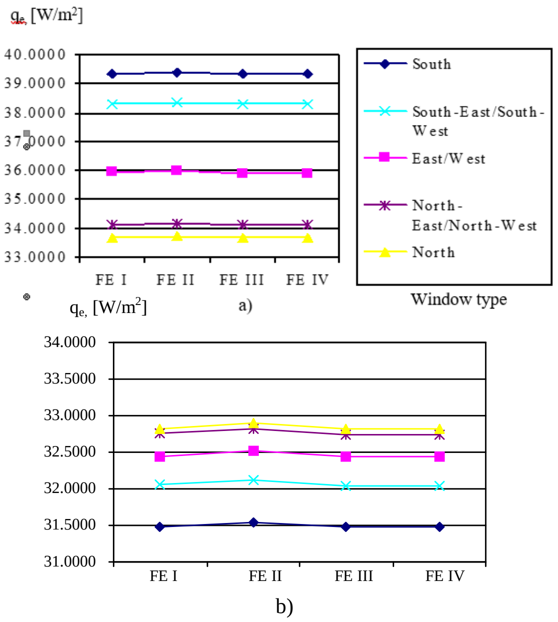

Fig. 3. Variations in heat flux density on the outside of the window, depending on its type: a) location inside the locality; b) location outside the locality.

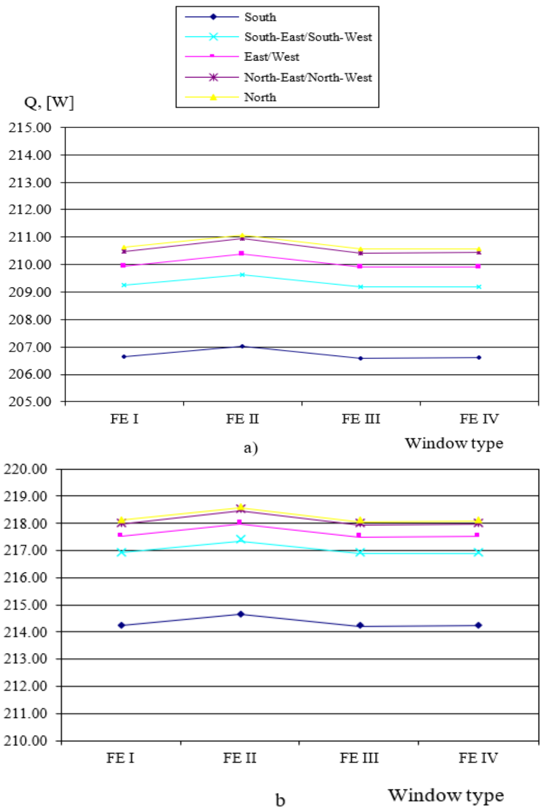

Fig.4.Variations in the total heat flux transmitted through the window, depending on its type: a) location inside the locality; b) location outside the locality.

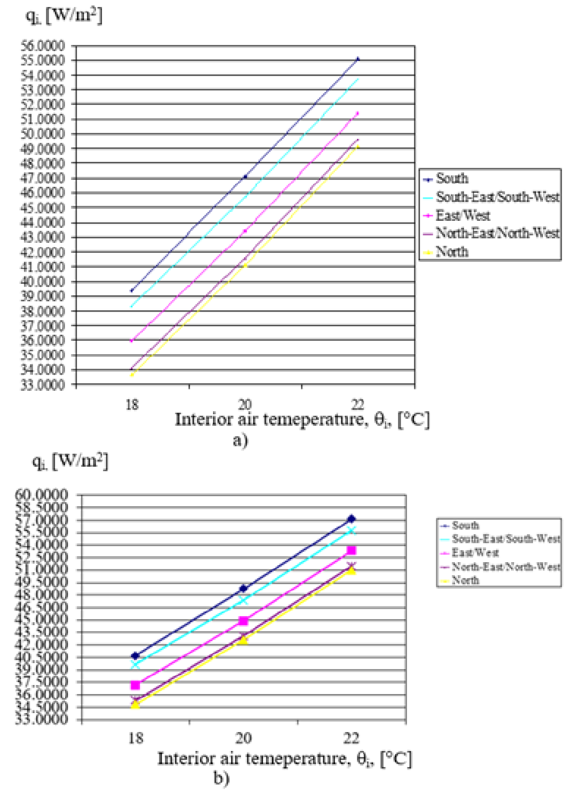

Fig 5.Variations in the heat flux density on the inside of the simple type I window, depending on the indoor air temperature and the location of the building: a) location inside the locality; b) location outside the locality.

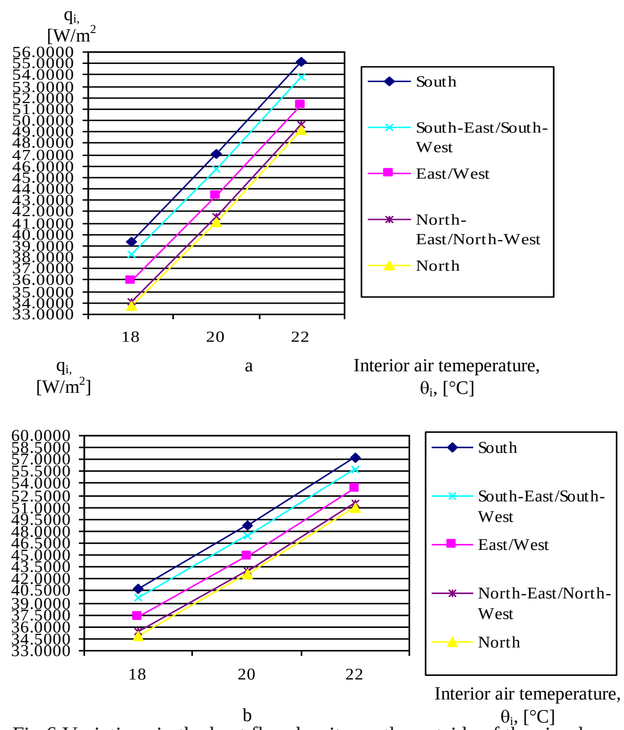

Fig.6.Variations in the heat flux density on the outside of the simple type I window, depending on the indoor air temperature and the location of the building: a) location inside the locality; b) location outside the locality.

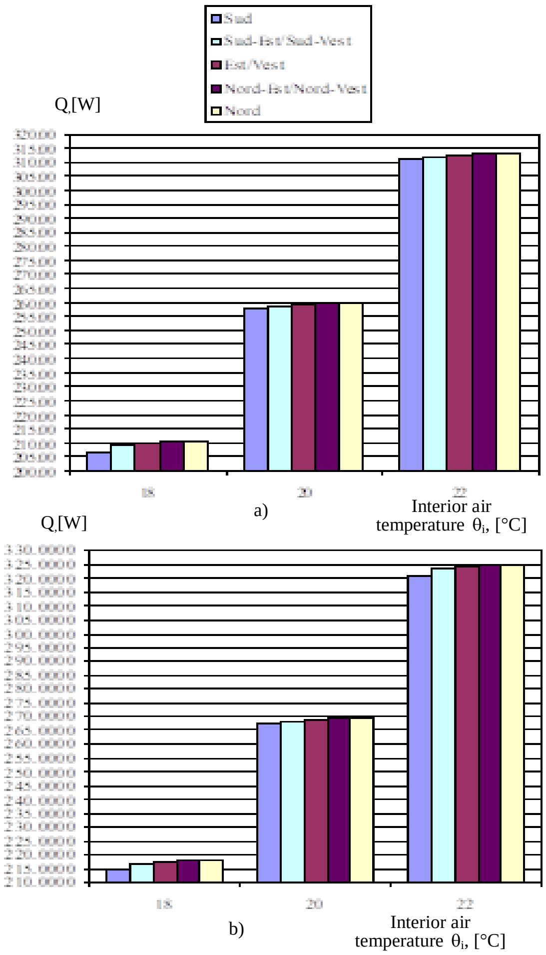

Fig.7.Variations of the total heat flux transmitted through the simple type I window, depending on the indoor air temperature and the location of the building: a) location inside the locality; b) location outside the locality.

IV. CONCLUSIONS

When modeling the radiant heat transfer, using the fictitious room calculation method, an explicit writing of the radiated heat fluxes between the considered surface and the fictitious room is obtained, which has the effect of eliminating the laborious solution of the linear system of radio modeling equations. Also, the application of this method of modeling radiant heat transfer introduces errors that can characterize a radiant balance other than zero, because the modeling does not take into account the actual exchange of heat by radiation between different surfaces of the room.

Elimination of this drawback is possible by calculating a real radiant balance and allocating the non-closing error by weighted measurement in relation to the surfaces. By doing this, the net flow values for each of the room surfaces are corrected by successive iterations.

By comparing the three families of models presented in the paper (approximation of form factors, fictitious room and radiant thermal resistances) that allow the calculation of the heat flux transmitted by radiation in mono zoned and multi zone models with the radiosity method, leads to minor differences (<10%) in the case of form factors close to 1, provided that the radiant heat transfer balance is prepared as accurately as possible.

The use of the three methods for estimating the radiant heat exchange in a room (approximation of form factors, fictitious room and radiant thermal resistance) leads to relevant results if no conditions other than those currently accepted in behavioral analyzes are required. thermal properties of buildings and their installations (gray and diffuse surfaces for the two spectral domains - large and short wavelength, isothermal surfaces and air considered a transparent medium for thermal radiation). From the analysis of the results obtained after simulating the heat transfer through a simple window, the following conclusions can be drawn:

The convergence of the real value of the temperature on the inner face of the simple windows presupposes in most cases the performance of 3 iterations;

The temperature on the inside of the window varies from 8.6976°C in the case of single type III window, to the location outside the locality and indoor air temperature of + 18°C, to a maximum of 9.8735°C in the case of single type II window , at the location inside the locality and a temperature of + 22°C;

The thermal convection coefficients on the inside of the window show quite small fluctuations depending on the indoor air temperature and the absorption of solar radiation (between 3.4918 W / (m^2·K) and 3.8440 W / (m^2·K)), being as value <4 W / (m^2·K);

The geographical orientation of the window, through the absorption index of solar radiation, influences the value of heat loss, regardless of the type of window, noting that the decrease of this parameter results in an increase in heat loss through the window;

In relation to the geographical orientation, so to the coefficient of absorption of solar radiation, it is observed that the unit heat flux to the inner face of the window increases with the reduction of solar radiation intensity, having values close to the values of unit heat flux to the outer face of the window. At high intensities of solar radiation q_i = (30.1252…31.4475) W/m^2, respectively q_e = (39.3752…40.7255) W/m^2, i.e. a difference of approximately (9.25 ...9,79) W/m^2, unlike if the intensity of the solar radiation is lower, in which case, q_i = (31,6467…32,8823) W/m^2, respectively q_e = (33,6767…34,8523) W/m^2, i.e. a difference of approximately (2.03...1.97) W/m^2;

The value of the convection coefficient on the outer face of the single window, with a window, regardless of its type, varies depending on the calculation wind speed, increasing almost 1.25 times for an increase in wind speed by 1.5 m/s, of at 23.25 W/(m^2·K) in case of location of the building inside the locality at 29.10 W/(m^2·K) in case of location of the building outside the locality;

The heat flow transmitted from the inside of the room to the outside environment depends on both the overall heat transfer coefficient and the temperature difference between the two environments separated by the window.

Thus, the global heat transfer coefficient has the lowest value in the case of the simple type III window, at the location in the locality of the building to which the respective window belongs and at an indoor air temperature of + 18°C (2.9813 W/(m^2·K)), which leads to a heat loss of 206.60 W, and the highest value is recorded in the case of a simple type IV window, outside the location of the building and at an indoor air temperature of + 22°C

(3.3948 W/(m^2·K)), which leads to a heat loss of 324.88 W. It is observed that at an increase of 13.87% of the global heat transfer coefficient, results in an increase in heat loss by more than 50%;

Heat losses through single windows reach the highest values in the case of simple type IV windows, in the case of buildings located outside the localities, regardless of the orientation and temperature of the air inside the room.

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