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IMPACT OF THE TRANSLUCENT STRUCTURES OF EXTERIOR WALL ENVELOPE ORIENTATION ON THE ENERGY BALANCE OF THE PREMISES

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Summary. *This article is devoted to the question of the influence of orientation, thermal resistance, and the coefficient of relative penetration of solar radiation (CRPSR) of the translucent structures of exterior wall envelope (TSEWE) on total heat loss during the heating period and its inflow in the cooling period. The aim of this study directed to determine the effect of both thermal resistance and CRPSR on the electricity consumption to compensate for heat losses and heat revenues through the TSEWE. As a result of research received the dependence of electricity consumption on the heating and cooling of the office space, from the CRPSR, the thermal resistance for different orientation of the TSEWE for the city of Ternopil. This made it possible to determine the influence of the orientation of the TSEWE on the heat input and heat loss of the premises with different parameters of the TSEWE. It is proved that during the year, the least amount of electric energy is spent to remove heat and compensate heat loss through the TSEWE, with its southern orientation (with thermal resistance ≤0.4 (m^2×°C)/W), while at a thermal resistance> 0,4 (m^2×°C)/W – at the northern.*

Key words*: glazing, window opening, WO, translucent structures of exterior wall envelope, TSEWE, orientation, heat revenues, heat losses, daylighting, coefficient of relative penetration of solar radiation.*

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Statement of the problem. Currently, in solving the question of lighting premises the main attention focused on the use of artificial light sources. According to the International Energy Agency datas, they consume about 19% from total world electricity production. The sunlight usage is one of the obvious ways to save electricity not only on lighting, but also on heating and air conditioning of premises. To this effect, it is enough correctly to determine the dimensions, orientation, thermotechnical characteristics and the coefficient of relative penetration of solar radiation (CRPSR) of the translucent structures of buildings. The implementation of this approach, for a long time was held back by the fact that, according to the thermotechnical characteristics, windows were weak link of the exterior wall envelope (EWE).

According to DBN V.2.6-31:2006, a modern metal-plastic construction, which are the main part of translucent structures of exterior wall envelope (TSEWE), have the same thermal insulation properties as a 60 cm wall with an ordinary solid loam brick on a cement-sand grout (0,75(m^2×°C)/W). Comply with DSTU-N B V.2.6-83:2009, the minimum thermal resistance of a triple-pane window is 0,75(m^2×°C)/W). The thermal resistance of opaque EWE has also increased significantly. For the first climatic zone, its value should be, according to DBN V.2.6-31:2016, not less than 3,3 (m^2×°C)/W. This make possible more effectively use of solar radiation for improving the energy efficiency of buildings.

Analysis of the available investigations showed that the questions of rational orientation of TSEWE on improving the energy efficiency of buildings were considered in [1, 2]. However, the authors did not take into account the heat input through the TSEWE from solar radiation during the heating and cooling periods. Researches have been conducted for only one value of thermal resistance. This is not enough to be able to talk about the reliability of the obtained results for other values of thermal resistance. Accordingly, it has not been established the influence of solar radiation, which penetrates inside the premises, on energy efficiency of buildings.

In [3] has been considered the question about heat input from solar radiation through the TSEWE of the southern facade at winter and summer periods of the year, by the use and absence of shading devices. The authors established that properly designed shading devices that in winter should not prevent heat earnings from solar radiation, and in summer they should reduce its penetration by several times. At the same time, the article did not describe the question of the influence of the orientation and the coefficient of relative penetration of solar radiation through the TSEWE on the amount of heat input into the building. In [4], was analysed the influence of thermotechnical characteristics of the TSEWE on the microclimate condition of the premises during the heating period. The authors determined the influence of integral thermal resistance of the TSEWE on the amount of heat loss during the heating period, but they did not focus on the seasons and the orientation of the TSEWE. In [5], were considered the questions about the influence of orientation and area of the TSEWE glazing on heat loss and heat input in office space with a certain value of thermal resistance. But it was refused by heat input from solar radiation in the heating period. In [6, 7, 8], was investigated the influence of the orientation and size of TSEWE on electricity consumption for heating and cooling of premises. It has been established that their orientation has a significant impact on power consumption both on heating and cooling. However, the influence of thermal resistance and the CRPSR into the premises were not taken into account.

The purpose of the research. To determine the influence of orientation, thermal resistance and coefficient of relative penetration of solar radiation of translucent structures of exterior wall envelope on the energy balance of translucent structures of premises.

Formulation of the problem. Proceeding from the above, no one of the above-mentioned authors by calculating the energy efficiency of buildings did not take into account the simultaneous influence of such factors as the orientation of the TSEWE, the heat input from solar radiation during the heating and cooling periods, the relative penetration rate of solar radiation into the premises of the TSEWE and their thermal resistance. That is why this article is aimed at solving the above-mentioned problem.

The presentation of the main material. Determination of heat loss through TSEWE with a different thermal resistance was carried out according to the methods given in SNiP II-4-79 and DSTU-N B A.2.2-5:2007. It has been considered the buildings, which parameters correspond to the requirements of the current regulatory documents of Ukraine when calculated (DSTU-N B V.2.6-83:2009, DBN B.2.5-28:2018, DSTU B V.2.6-23:2009, DBN V.2.6-31:2016, DSTU B EN 15251, SNiP II-33-75, DSTU-N B A.2.2-5:2007 and DSTU-N B C.1.1-27:2010).

In accordance with them, were selected the target values of building envelopes and the environmental one. All calculations were carried out for the city of Ternopil (geographical coordinates 49 ° 34 N 25 ° 36 E). Waste of the heat energy was defined as the difference between the lossines through the TSEWE and the wall.

The indoor workplace temperature for the heating system was adopted in accordance with DSTU-N B EN 15251, which is + 20°C, and the cooling system + 26°C. The TSEWE area was taken equal to 1 m^2. Heat resistance varied from 0,1 to 3,3 (m^2·°C)/W. Waste of the heat energy through TSEWE ω_{H}, (kW·h)/year with the option of standby heating during off-hours, according to SNiP II-4-79, were calculated by the formula (1)

$$\omega_{\text{H}} = \begin{pmatrix} 10^{-3} \cdot 1{,}1 \cdot (1{,}3+\eta) \cdot \left(1/R_{\text{TSEWE}} - 1/R_{\text{E}}\right) \cdot z_{\text{HP}} \cdot \overline{s} \cdot S_{\text{WE}} \times \\ \times \left[(t - t_{\text{AV.OUTD.}}) \cdot T + (t_{\text{ST.}} - t_{\text{AV.OUTD.}}) \cdot (8760 - T)\right] \end{pmatrix} / 365, \text{ (kW·h)/(year)} \quad (1)$$

where 1,1 – is the coefficient, which takes into account heat losses in heating systems, according to SNiP II-4-79, rel. units;
1,3 – is the coefficient which takes into account heat losses on heating the external air entering through TSEWE, according to SNiP II-4-79, rel. units;
η – is the coefficient which takes into account the additional heat losses through the EWE, it selected from the Table 2, add. 5 SNiP II-33-75 * (see Table 1), rel. units;
R_{TSEWE} – thermal resistance of TSEWE, (m^2·°C)/W;
R_E – economically attractive thermal resistance of the dumb part of the covering (when calculated heat losses through roof lamps) or walls (when calculated heat losses through windows), (m^2·°C)/W, is determined by DBN B.2.6-31: 2016;
$t_{AV.OUTD.}$ – average outdoor temperature for the heating period, °C;
t – the estimated winter air temperature indoors during working hours, °C, in accordance with DSTU B EN 15251;
T – annual working hours, taken in 2150 hours – when working in one shift; 4300 hours – when working in two shifts; 6500 h – when working in three shifts, h/year;
S_{TSEWE} – area of the window embrasure in the wall or cover, m^2;
z_{HP} – the duration of the heating period for residential premises, days, is chosen in the form of DSTU-N B V.1.1-27:2010;
$\bar{s}$ – relative area of TSEWE glazing, relative units.

From [9, 10] it is known that the relative area of glazing depends from the proportions of TSEWE, and thermal resistance from the size of the area of its profile, glazing and foaming. Therefore, for the best representativeness of the results, we will take TSEWE homogeneous (with the same thermal resistance), and its relative glazing area will be equal 1.

Table 1

Additional heat losrss for external vertical and inclined (vertical projection) walls, doors and TSEWE

Windows' orientation	South	North, East	West
η, %	0	10	5

When determining heat losses through the building envelope, the value of the calculated air temperature inside of the building (room) up to 4 m high is taken according to [11], equal to the air temperature in the workplace ($t=t_W$). The air temperature in the workplace is selected from DSTU B EN 15251.

Beyond working hours during standby heating the air temperature inside the premises (t_{ST}) was assumed to be equal 5°C for industrial and 10–12°C for the all office premises [12]. When carrying out calculations of heat energy losses through TSEWE, the data given in Table 2 were taken as initial data.

Table 2

Initial data for determining heat losses through TSEWE for the city of Ternopil

Target value	$t_{AV.OUTD.}$, °C	T, hour/year	R_E, m^2·°C/W	z_{HP}, days	t, °C	t_{ST}, °C
Value	-0,2	2150	3,3	184	20	12

The expression for determining the heat losses during the heating period ω_{H}, (kW·h)/year through the TSEWE area by 1 m^2 for the Ternopil city on the assumption that there is an option of standby heating during off-hours which are given by (2), and without (3)

$$\omega_{\text{H}} = 89,44 \cdot S_{\text{TSEWE}} \cdot (1,3 + \eta) \cdot \left(1 / R_{\text{TSEWE}} - 1 / R_{\text{E}}\right), \text{ (kW·hour)/year.} \quad (2)$$

$$\omega_{\text{H}} = 31,31 \cdot S_{\text{WE}} \cdot (1,3 + \eta) \cdot \left(1 / R_{\text{TSEWE}} - 1 / R_{\text{E}}\right), \text{ (kW·hour)/year.} \quad (3)$$

On the fig. 1 represented the graphs for the cases of presence (Fig. 2, a) and the absence (Fig. 2, b) of the standby heating.

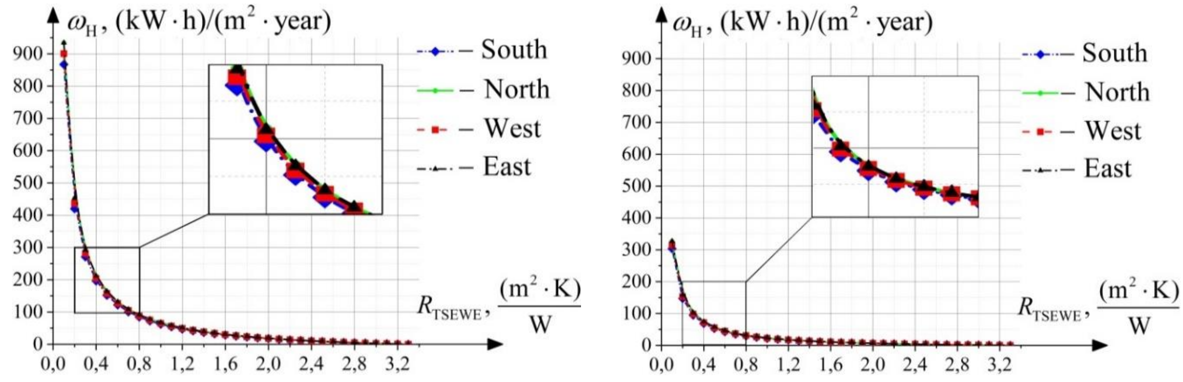


Figure 1. Dependence of heat energy losses through TSEWE by the area of 1 m2 from orientation and heat resistance in case of: a) availability of standby heating; b) visibility of standby heating

As can be seen from the fig. 1, with an increasing of thermal resistance, decreasing of heat energy losses through a TSEWE occurs by a hyperbolic law, which expresses the inverse proportionality between the argument and the function.

So, for the western orientation and availability of standby heating with an increasing of thermal resistance in 4 times from 0,1 to 0,4 (m^2·°C)/W, the losses of thermal energy decrease from 900,7 to 204,1 (kW·h)/year, that is, at 696,6 (kW·h)/year. At the same time, when thermal resistance increasing by 5 times from 0,4 to 2,0 (m^2×°C)/W, the losses of thermal energy decreases from 204,1 to 18,3 (kW×h)/year, so only at 185,8 (kW·h)/year. This is in 3,75 times less than in the previous case.

Thus, an increasing of thermal resistance definately leads to a decreasing intensity of heat energy losses, in other words to the increasing of energy efficiency of buildings. By the absence of standby heating and by increasing of thermal resistance in 4 times from 0,1 to 0,4 (kW×h)/year, the losses of thermal energy decrease from 315,27 to 71,43, in other words it is on 243,84 (kW×h)/year. While increasing of thermal resistance from 0,4 to 2,0 (m^2×°C)/W, the losses of thermal energy decreases from 71,43 to 6,4 (kW×h)/year, that is only on 65,03 (kW×h)/year. That is in 3,75 times less than in the previous case. Thus, in the absence of standby heating, the losses of heat energy through a TSEWE by 1 m^2 decreases, according to (3), in 2,86 times as in comparison with the case when standby heating was used.

Due to the fact that heat losses through the TSEWE are directly proportional to its area, expressions (2) and (3) can be used to calculate windows of any size. Since the dependence of heat losses through the TSEWE from orientation is characterized only by the coefficient of additional heat losses, so the total losses will be differing from them by the same value (see Table 1).

Incoming of solar radiation through the TSEWE by the heating period (kW · h), for the facades of the house oriented in four directions – South (S), North (T), West (W) and East (E), we determined, according to DSTU-N B A.2.2-5-2007, by expression (4)

$$Q_{\text{H}} = \zeta_{\text{TSEWE}} \cdot \varepsilon_{\text{TSEWE}} \cdot (S_{\text{S}} \cdot I_{\text{N}} + S_{\text{N}} \cdot I_{\text{N}} + S_{\text{W}} \cdot I_{\text{W}} + S_{\text{E}} \cdot I_{\text{E}}), \text{(kW·hour)/year}, \tag{4}$$

where ζ_{TSEWE} – the coefficient that taking into account the shading of the TSEWE opaque elements, it was selected from the Table 1, DSTU-NB A.2.2-5-2007, rel. units;
$\varepsilon_{\text{TSEWE}}$ – the coefficient of relative penetration of solar radiation for TSEWE, relative units;
S_{S}, S_{N}, S_{W}, S_{E} – the TSEWE area in the facades of the building, oriented to South, North, West and East, m^2, respectively;
I_{S}, I_{N}, I_{W}, I_{E} – the average value of solar radiation for the heating period, directed to a vertical surface in cloudy conditions, and oriented accordingly to South, North, West and East, is selected from the Table 2 DSTU-N B A.2.2-5-2007 (kW · h)/m^2.

The initial data for determining the incoming of solar radiation through the TSEWE for the heating period for the Ternopil city is given in Table 3

Table 3

Initial data for calculation the incoming of solar radiation through the TSEWE by the heating period

Quantity	ζ_{TSEWE}	S_{TSEWE}	I_{S}	I_{N}	I_{W}	I_{E}
Value	0,75	1	249,2	86,1	145,6	142,2

Incoming of heat energy Q_{H} kWh/year during the heating period from TSEWE with an area of 1 m^2 of western orientation with CRPSR equal to 0,5 is

$$Q_{\text{H}} = 0,75 \cdot 0,5 \cdot 1 \cdot 145,6 = 54,6 .$$

The highest value of radiation incoming of heat into the working area ($Q_{\text{C}}^{\text{MAX}}$, kWh/year) during the cooling period is determined by the maximum value of total solar radiation incoming on the TSEWE area during the day and is calculated according to SNiP II-4-79, by the formula (5).

$$Q_{\text{C}}^{\text{MAX}} = \left(Q_{\text{DIR.R.VII}}^{\text{MAX}} + Q_{\text{DIF.R.VII}}^{\text{MAX}}\right) \cdot \varepsilon_{\text{TSEWE}} \cdot \tau_2 \cdot \tau_3 \cdot \tau_4 \cdot \overline{s} \cdot S_{\text{TSEWE}} \cdot T_{\text{C}} \cdot 10^{-3}, \text{(kW·hour)/year} \tag{5}$$

where $Q_{\text{DIR.R.VII}}^{\text{MAX}}$ – the highest value of direct solar radiation in July at the time of a cloudless sky on a vertical surface by a certain orientation, W/m^2, is determined from DSTU-N B V.1.1-27:2010;
$Q_{\text{DIF.R.VII}}^{\text{MAX}}$ – the highest value of diffuse solar radiation in July in the cloudless sky on the vertical surface of a certain orientation, W/m^2, is determined from DSTU-N B V.1.1-27:2010;
τ_2 – the coefficient that takes into account the light loss of the translucent hole bindings, was taken by DBN B.2.5-28: 2018, rel.;
τ_3 – the coefficient that takes into account the decreasing of heat gains due to a glass pollution, rel. units were taken from the Table 5, add. 12 SNiP II-33-75*;

τ_4 – the coefficient of heat transmission of shading devices, taken by DBN B.2.5-28:2018, rel. unit;
T_C – duration of the cooling system work, is determined from [13], h/year.

The initial data for the calculation of the highest value of radiation heat input into the working area are given in Table 4.

Table 4

Initial data for calculating the highest value of radiation heat input into the work area

Target quality	τ_2, relat. un.	τ_3, relat. un.	τ_4, relat. un.	N_{TSEWE}, pcs	T_C, hour/year
Value	0,75	0,9	1	1	423

The meaning of the environmental conditions for the calculation of the largest radiation heat input into the working area, for the Ternopil city, according to DSTU-N B V.1.1-27:2010, is given in the Table 5.

Table 5

The highest value of solar radiation in July with a cloudless sky on a vertical surface of a certain orientation

Orientation	N	NE	E	SE	S	SW	W	NW
Direct ($Q^{MAX}_{DIR.R.VII}$), W/m^2	70	264	512	476	374	476	512	370
Diffused ($Q^{MAX}_{DIF.R.VII}$), W/m^2	55	109	146	145	136	145	146	92

Expressions (6), (7) and (8) make it possible to determine the highest value of radiation heat input into the working area (kW·h)/(m^2 year) for the Ternopil city, for TSEWE which is oriented:

– to the South:

$$Q^{MAX}_C = 145,62 \cdot S_{TSEWE} \cdot \varepsilon_{TSEWE}, \text{ (kW·hour)/year,} \tag{6}$$

– to the North:

$$Q^{MAX}_C = 35,69 \cdot S_{TSEWE} \cdot \varepsilon_{TSEWE}, \text{ (kW·hour)/year,} \tag{7}$$

– to the West and East:

$$Q^{MAX}_C = 187,88 \cdot S_{TSEWE} \cdot \varepsilon_{TSEWE}, \text{ (kW·hour)/year.} \tag{8}$$

The results of the highest value calculations of radiation heat input in the working area of the premise for the Ternopicity, are shown on the Fig. 2

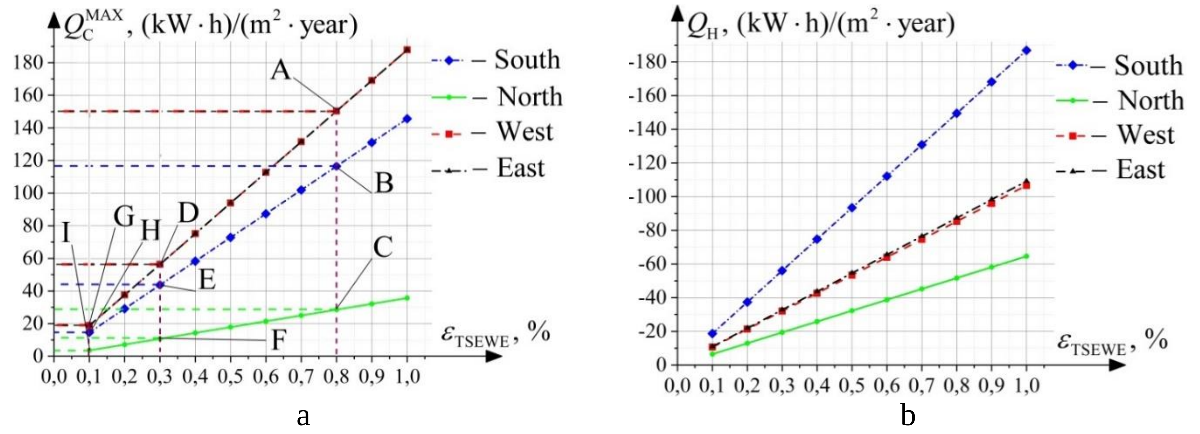


Figure 2. Dependence of the incoming solar radiation through the TSEWE by the area of 1 m^2 with a change of orientation and *CRPSR* during: a) the cooling period; b) the heating period

As can be seen from (3) and from fig. 2, heat input through TSEWE are directly proportional to the value of the coefficient of relative penetration of solar radiation. For the Ternopil city, heat inputs through TSEWE of the eastern and western orientation almost do not differ. The maximum amount of thermal energy during the cooling period enters through the TSEWE of eastern and western orientation. At the heating period – the southern orientation.

To determine the total annual energy consumption for heating and cooling (ω) is necessary to determine the unit cost of electricity by modern devices for heating and cooling. Since the data specified in [14, 15] are outdated (in the first case, they were determined for adiabatic cooling, and in the second – almost 20 years ago) it was decided to determine the value of the cost per unit of electricity consumption for removal and supply of 1 kW □ h of thermal energy when using modern air conditioners.

Inasmuch as heat-insulating materials and metal-plastic TSEWEs do not provide adequate air entry into the room, it is necessary to use devices that are able to supply fresh air to the outside environment. Nowadays a universal solution for ventilation, heating and cooling of premises are channel air conditioners. They are compact and can be installed in premises where the ventilation system at the construction stage was not foreseen.

For determining the current value of the cost per unit energy consumption for ventilation and air cooling by channel air conditioners, it was analyzed the model range of the Neoclima company (Table 6) [16].

Table 6

Parameters of channel inverter-free air conditioners of the Neoclima company

Title	Cooling			Heating		
	Nominal rating power, W	Power of cooling, W	*EER* W/W	Nominal rating power, W	Power of heating, W	*COP*, W/W
1	2	3	4	5	6	7
NDS12AH1me	1268	3725	2,94	1198	3810	3,18
NDS18AH1me	1857	5030	2,71	1621	5570	3,44
NDS24AH1me	2459	6640	2,70	2287	7260	3,17
NDS36AH3me	3624	9850	2,72	3438	11725	3,41
NDS48AH3me	4790	13100	2,73	4405	16100	3,65
NDS60AH3me	6114	16450	2,69	5087	17880	3,51

to be continued3

1	2	3	4	5	6	7
NDS18AH1mes	1857	5030	2,71	1621	5570	3,44
NDS24AH1mes	2459	6640	2,70	2287	7260	3,17
NDS36AH3mes	3624	9850	2,72	3438	11725	3,41
NDS48AH3mes	4790	13100	2,73	4405	16100	3,65
NDS60AH3mes	6114	16450	2,69	5087	17880	3,51
Average value			**2,73**			**3,41**

In accordance with the Resolution of the Cabinet Ministers of Ukraine dated by May 24, 2017 № 360, the following definitions were adopted on the approval of the technical regulations for energy labeling of air conditioners:

– nominal capacity means consumed electric power for cooling or heating of the compression cycle of the installation under standard evaluation conditions;

– cooling/heating power means the power that is removed/supplied through the air conditioner when the rated power is consumed by the installation of a compression cycle under standard evaluation conditions;

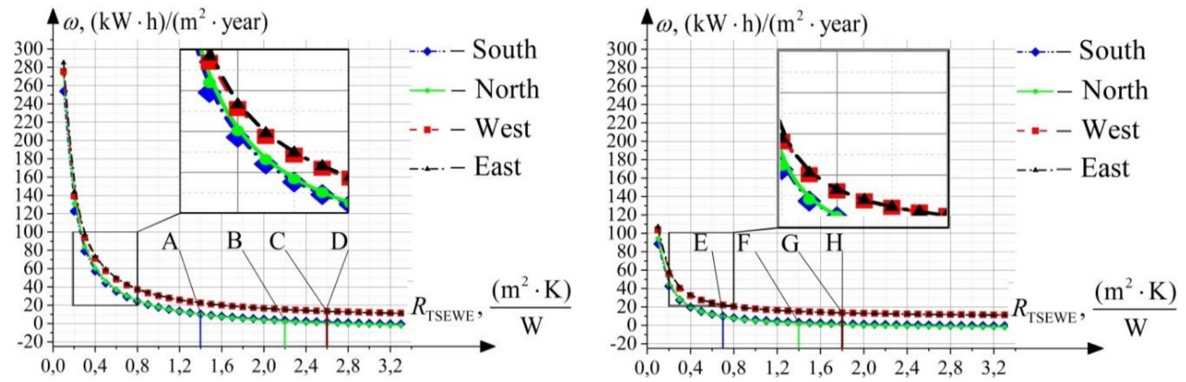
– energy efficiency ratio) (*EER*) means declared power for air cooling [kW] divided by input nominal power for cooling [kW] of the room under standard test conditions;

– coefficient of performance) (*COP*) means the declared power for air heating [kW] divided by the input rated power for heating [kW] of the room, which provides heating under standard test conditions.

Since for rooms of various sizes and with a different number of workers, the cooling system must be calculated separately, to simplify calculations, we used the average value of the passport data of modern air conditioners (Table 6). Electricity consumption for the operation of the air conditioner to compensate of heat losses and heat inputs through TSEWE were determined by the expression (9).

$$\omega = (\omega_{\text{H}} - Q_{\text{H}}) / COP + Q_{\text{C}}^{\text{MAX}} / EER, \text{ (kW·hour)/year.} \qquad (9)$$

The results of electricity consumption calculation for compensation of heat losses and heat inputs through the TSEWE for the Ternopil city with a TSEWE area by 1 m^2 shown on a Fig. 3 (for 0,3 CRPSR value) and on a fig. 4 (for 0,8 CRPSR value).



a b

Figure 3. The dependences of the electricity costs by compensation of heat losses and heat inputs through TSEWE area by 1 m^2 with *CRPSR* 0,3 from its orientation and thermal resistance: a) with the standby heating; b) without standby heating

As a minimum thermal resistance of the TSEWE, has been taken that value, in which the electricity consumed by the air conditioner per year is equal to the electricity saved by the heating period (Fig. 2, b). The practical implementation of this approach is currently impossible because for this purpose is needed TSEWE with a thermal resistance greater than 2,0(m^2 °C)/W (Fig. 3, 4). Real thermal resistance of TSEWE does not exceed 1,2(m^2·°C)/W.

For this reason, when specifying necessary thermal resistance, was considered an option using of solid homogeneous shading devices. When using them in summer period for TSEWE with CRPSR equal to 0,3, the resulting CRPSR is assumed to be equal 0,1. So, from the value of the total electricity consumed (Fig. 3, a, point A, point B, point. C, point D when using standby heating) and (Fig. 3, b, point E, point F, point G, point H without the use of standby heating) took the amount of consumed electricity to remove heat inputs (Fig. 2, a). The same calculations have been carried out and at the CRPSR value of the TSEWE equal to 0,8 (Fig. 4, a) and (Fig. 4, b), with the resulting value of 0,5 (Fig. 2, a).

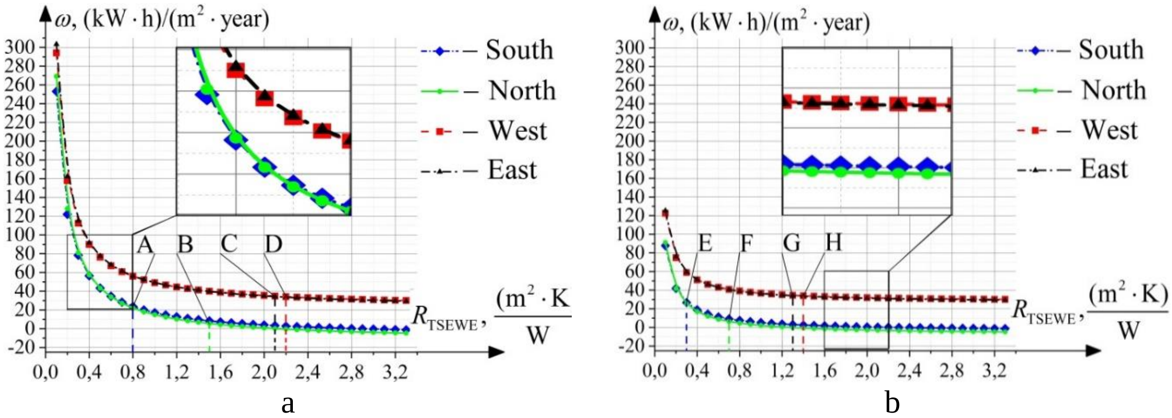


Figure 4. The dependences of the electricity costs by compensation of heat losses and heat inputs through TSEWE area by 1 m^2 with *CRPSR* 0,8 from its orientation and thermal resistance: a) with the standby heating; b) without standby heating

As a result, it was established that when using shading devices in summer for TSEWE with CRPSR equal to 0,8, there is come out an energy saving in the presence of standby heating. With thermal resistance of 0,8(m^2×°C)/W for the south orientation, 1,6(m^2×°C)/W for the north and 2,2(m^2×°C)/W and 2,3(m^2×°C)/W for the east and west, respectively (Fig. 4, a). While there is no standby heating – for the southern, northern, eastern and western orientation, respectively (Fig. 4, a). As can be seen from fig. 3 and fig. 4 greater energy savings are observed in TSEWE with a larger CRPSR and without standby heating

Based on the obtained results, it can be argued that using of shading devices for reducing the CRPSR of a translucent external enclosing structure can significantly improve its energy efficiency of buildings. It should also be noted that this study did not take into account energy savings due to the use of daylighting, which comes through TSEWE. This significantly increases the energy efficiency of using TSEWE.

It should be emphasized, that only heating and cooling periods were taken into account, during calculations of electricity consumption for heating and cooling of the premises. The heat balance on other days has not been taken into account. For the city of Ternopil, the heating period lasts from 14.10 to 16.04, according to DSTU-N B V.1.1-27: 2010, and cooling period – from 08.06 to 26.08 [13], then 110 days between these periods are not taken into account. And this is an additional heat transfer through the TSEWE of southern orientation for 110 days, which increases the comfort of stay indoors, but does not affect the cost of electricity.

Conclusions. It has been confirmed by calculations that when using background heating, the rate of change heat energy losses through TSEWE sharply decreasing with an increasing of thermal resistance (Fig. 1, a). It has been established that the maximum inflows of solar radiation through the TSEWE for the Ternopil city during the cooling period were observed with the western and eastern orientation. In the heating period – with a southern orientation (Fig. 2). It has been proved that when thermal resistance ≤ 0,4 ($m^2 \times$ °C)/W annual minimum of energy consumption for heat removal and compensation of heat losses through TSEWE, it observed at its southern orientation. When thermal resistance > 0,4 ($m^2 \times$ °C)/W – at the northern orientation. It has been established that the use of shading devices during the cooling period for TSEWE with CRPSR 0.8, with certain values of thermal resistance for each orientation of the TSEWE, leads to a decrease in electricity consumption compared to the depleted EWE (Fig. 4, a).

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ВПЛИВ ОРІЄНТАЦІЇ СВІТЛОПРОЗОРОЇ ЗОВНІШНЬОЇ ОГОРОДЖУВАЛЬНОЇ КОНСТРУКЦІЇ НА ЕНЕРГЕТИЧНИЙ БАЛАНС ПРИМІЩЕННЯ

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Резюме. *Найпоширенішим способом введення сонячного світла в приміщення є використання системи бокового освітлення. Тому дослідження параметрів, які впливають на ефективність бокового природного освітлення, особливо на фоні тотального використання сучасних енергоефективних вікон, не втратили своєї актуальності. Дана стаття присвячена питанню впливу орієнтації, термічного опору та коефіцієнта відносного проникнення сонячної радіації (КВПСР) віконного прорізу (ВП) на сумарні втрати тепла в опалювальний період та його надходження в охолоджувальний період. Це важливо, тому що на даний час немає рекомендацій щодо значення параметрів СЗОК, за яких досягатиметься максимальна енергоефективністсть. На сьогодні основним параметром, за яким обирають металопластикові віконні конструкції, є її термічний опір. Значенням КВПСР зазвичай нехтують. Дане дослідження спрямоване на визначення впливу як термічного опору і КВПСР на витрати електроенергії для компенсації тепловтрат та теплонадходжень через СЗОК. У результаті досліджень отримано залежності витрат електроенергії на опалення та охолодження офісного приміщення від КВПСР термічного опору при зміні орієнтації СЗОК для м. Тернопіль. Це дало можливість визначити вплив орієнтації СЗОК на теплонадходження та тепловтрати приміщення за різних параметрів СЗОК. Доведено, що за рік найменше електроенергії затрачається для видалення тепла та компенсації тепловтрат через СЗОК при південній його орієнтації (при термічному опору ≤0,4), в той час, як при термічному опорі >0,4 – при північній орієнтації. Що дає можливість стверджувати, що західна та східна орієнтації СЗОК є найменш доцільними з точки зору енергоефективності. Отримані результати дозволяють у подальшому провести визначення параметрів СЗОК, за яких досягатиметься економія електроенергії з урахуванням зменшення її споживання на штучне освітлення.*

Ключові слова*: засклення, віконний проріз, ВП, світлопрозора зовнішня загороджувальна конструкція, СЗОК, орієнтація, теплонадходження, втрати тепла, природне освітлення, коефіцієнт пропускання світла.*

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