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DEPENDENCES OF RELATIVE AND ABSOLUTE GLAZED AREA FROM CONFIGURATION AND COMMON AREAS OF WINDOW EMBRASURE

Mykola Tarasenko; Vitaliy Burmaka; Kateryna Kozak

Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine

Summary. *The article deals with the economy of electric energy, which is spent on room lighting, because of increasing interests of natural light. As a result of the research, there has been obtained an analytical expression for determination of the absolute and relative glazed area of window embrasure of any configuration. This gives an opportunity (taking into account the costs of manufacturing) to choose a rectangular as the main configuration. It has been proved that only on the dependences of glazed area from window embrasure it is possible to come arrive to a decision with an acceptable range of metal-plastic window sizes in terms of providing high natural illumination of the premises.*

Key words*: glazing, profile, window, relative area, relative width of window embrasure, natural illumination, foam filling, glass unit, window form.*

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Problem setting. The usage of sunlight for indoor lighting is one of the obvious ways of saving electricity. Biologically Human adapted to a free natural light. Its optimal usage is capable for significantly decrease of electric energy consumption on artificial illumination. To achieve this, it is necessary to select correctly the dimensions and thermal characteristics of translucent structures (windows). Until recently namely the windows were the weakest link in the exterior wall envelope of buildings by this parameter.

Taking into account that the thermotechnical characteristics of modern translucent structures significantly increased, it's become possible for increasing of the glased area of foresides. This will allow not only more efficiently make use of natural lighting in construction, but also to feel the light as a process rather than a static situation. Sunrise is associated with the expectation that life start to wake up. Sunset is associated with the end of day work and with the transition to the evening until the night rest. The human body adapted to this 24-hour rhythm. Therefore, we should not feel the lighting as something static, but understand it as a dynamic feature of the visual climate of the interior.

That is why the leading specialists of the developed countries consider particularly topical the question of the correct organization of natural lighting of various kinds of premises. Only one type of lighting usage in most cases is not only irrational, but also does not fail to meet the requirements of human in preserving health.

Thus, the general lack of natural light, in accordance with the norms of occupational safety, is classified as harmful. Rooms without natural light is even hard to imagine.

Analysis of previous investigations. It has been showed [1-12] that at the present time it has become particularly topical the task of identifying among the existing plurality of premises with a fixed total area such, which in order to maintain comfortable conditions in them, requires minimal energy resources.

The aim of the investigation. Taking into account the significant influence of translucent structures on the quality of visual climate of the interior, we can confidently highlight actuality of item for increasing the proportion of natural light based on the usage of modern windows design in premises of any destination. That is why the purpose of the first

Corresponding author: Mykola Tarasenko; e-mail: tarasenko_mykola@ukr.net

stage of this work has become to establish of relative and absolute glazing areas dependences from the total area of the window embrasure of the violent configuration.

Realization of the investigation. Modern metal-plastic windows (MPW) were selected as translucent structures of exterior wall envelope (TSEWE). The design features of MPW shape allow to reduce not only energy costs for maintaining of comfortable human living conditions, but also the level of urban noise that can penetrate to the buildings. Getting rid of annual gluing and ungluing of windows.

Glass unit is one of the main components of a modern metal-plastic window. All-time among the window makers, take place a polemic over the importance of the components of the TSEWE. But, as a rule, everything comes down to profile and accessories. For some reasons, other details are missed out. Although on the integral thermal resistance of TSEWE influenced not only profile, accessories, and glass unit, but also mounting quality. Low-quality mounting can significantly reduce the total thermal resistance of the TSEWE.

The structure of the glass unit window is based on two or more glasses, on the perimeter of which is remote a distance-type frame. The received construction is treated with a special glue along the edges, which makes it completely hermetic. Inside, between the glasses, formed air chambers, which are the main element in double glasses. They are creating an insurmountable barrier between the exterior and the heating part of the premises. This prevents the leakage of heat and contributes to more efficient work of the heating system.

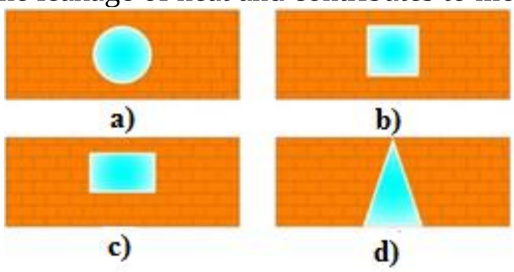

Figure 1. Outward of the wall with: a) round; b) square; c) square-angled; d) triangular window by the same area

To determine the parameters that influence on luminous efficacy of the sidelight of the premises, there has been analyzed the following configurations of windows with the same area of window embrasure: round, square, rectangular with proportions of the golden section (height-to-width aspect ratio 1,618: 1) and triangular also according to the proportions of the golden section (height to basilad ratio3:2) (fig. 1).

Calculations, as expected, showed (table 1), that the largest area of glazing is typical for round windows, after them followed square, then rectangular and triangular with the ratio of the golden section sides.

Table 1

The relative area of glazed windows embrazure from different configuration with 3 m^2 area

	Window configuration			
	Round	Square	Square-angled	Triangular
The relative area of glazed window embrazure, S_{GL}, %	84,297	82,378	81,841	79,033

In spite of the fact that round windows (illuminators) by parameters of window embrasure glazing are the best, their production is rather complicated and therefore they are the most expensive. In triangular windows the area of glazing is the smallest and they are not suitable for usage in the body of wall envelope of buildings. The best to use round and triangular windows under the roof of the building. Therefore, for determination of dependences of the relative area of glazing ($\bar{s}$) from the total area of window embrasure for the given: the area of the window embrasure (S_{WE}), profile width ($l_{\text{PROF.}}$) and the foam filling width (l_{FF}) (fig. 2) we selected rectangular MPW (fig. 3). At the present time they are not considered as a luxury item. This is already an integral part of not only the building, but also for people who care about personal health and the health of relatives. It is known that the area of a rectangular window embrasure determined by the formula:

$$S_{WE} = l_{WE} \cdot h_{WE}, \text{ m}^2, \quad (1)$$

where l_{WE}, h_{WE} – the width and height of the window embrasure rectangular, respectively, m.

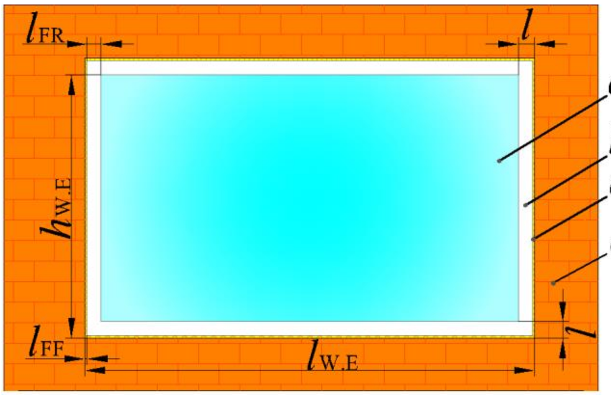

Figure 2. Schematic representation of a rectangular window embrazure: a) glazing; b) profile; c) foam filling; d) opaque building envelope

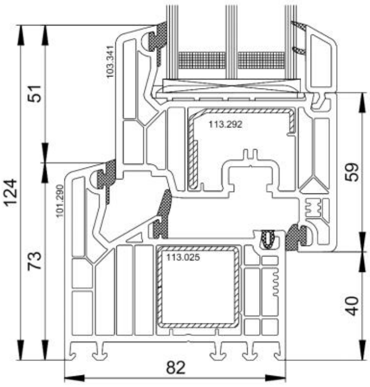

Figure 3. The scheme of the metal plate window profile of the system Veka SOFT-LINE 82

To determine the height and width of the rectangular of windows slots of any dimensions from expression (1), we use the concept of the coordination index ($i_{C.WE}$) of the window embrasure.

$$i_{C.WE} = l_{WE} / h_{WE} \text{, relative units} \quad (2)$$

Then, the equation (1) will take the form (3), and in the known area of the window embrasure (S_{WE}) its height (h_{WE}) and width (l_{WE}) will be determined by the expressions (4), (5)

$$S_{WE} = h_{WE} \cdot i_{C.WE} \cdot h_{WE} = i_{C.WE} \cdot h_{WE}{}^2, \text{ m}^2; \quad (3)$$

$$h_{WE} = \sqrt{S_{WE} / i_{C.WE}}, \text{m}; \quad (4) \qquad l_{WE} = \sqrt{S_{WE} \cdot i_{C.WE}}, \text{ m}. \quad (5)$$

The width of the window embrasure opaque part (l) will be determine as the sum of the width of the profile $l_{\text{PROF.}}$ and the foam filling l_{FF} (6)

$$l = l_{\text{PROF.}} + l_{FF}, \text{ m}, \quad (6)$$

where $l_{\text{PROF.}}$ – width profile, m [12, 8];

l_{FF} – foam filling width (see fig. 2), which according to the norms [13] is determining to the relevant size of the window embrasure. Proceeding from the standard size of the mounting fit, the foam filling width (l_{FF}) is taken equal: 10-15 mm - for window embrasure with side less than 2500 mm; 15-33 mm - for window embrasure with side from 2500 mm to 4500 mm and 30 mm - for window embrasure with side more than 4500 mm. Or we can use the expressions which we received as a result of approximation of standard sizes [13].

$$\begin{cases} if\ \ l_{WE} > h_{WE},\ \text{то}\ l_{FF} = (125 \cdot l_{WE}^2 \text{ -}123 \cdot l_{WE} + 1050) \cdot 10^{-2}\ \text{mm}, \\ if\ \ l_{WE} < h_{WE},\ \text{то}\ l_{FF} = (125 \cdot h_{WE}^2 \text{ -}123 \cdot h_{WE} + 1050) \cdot 10^{-2}\text{mm}, \\ \text{if}\ l_{WE}\ \text{або}\ h_{WE} \geq 4,5\ \text{m},\ \textit{accepting}\ l_{FF} = 30\ \text{mm}. \end{cases}$$

The dimensions of WE with the selected proportions for the corresponding area of the window profile are shown in table 2.

Table 2

The dimensions of the window embrasure area by 6 m^2, for different values of coordination index

Coordination index WE ($i_{C.WE}$)	1/1	2/1	3/1	4/1	6/1	8/1	12/1	18/1	24/1
Width, l_{WE}, m	2,45	3,46	4,24	4,90	6,00	6,93	8,49	10,39	12,0
Height, h_{WE}, m	2,45	1,73	1,41	1,22	1,00	0,87	0,71	0,58	0,50

Therefore, with the width of the window profile for the blank window 0,073 m, the width of the opaque part of the window embrasure (l) which occupied by profile and the foam filling, is equal according (6) to the values given in the table 3.

Table 3

The width of the opaque part of WE (l), for the window embrasure of 6 m^2 area, with differently height-to-width aspect ratio, m

Coordination index WE ($i_{C.WE}$)	1/1	2/1	3/1	4/1	6/1	8/1	12/1	18/1	24/1
Width of the opaque part WE, m	0,086	0,096	0,096	0,103	0,103	0,103	0,103	0,103	0,103

There has been received dependencies which allowed, after simple transformations, to get formulas for determining the absolute (formulas 7, 8, 9) and relative (formulas 10, 11, 12) area of glazing S_{GL} ($\bar{s}_{GL}$), the foam filling S_{FF} ($\bar{s}_{FF}$) and the profile $S_{\text{PROF.}}$ ($\bar{s}_{\text{PROF.}}$) in window embrasure of a rectangular shape with given sizes.

$$S_{GL} = l_{WE} \cdot h_{WE} - 2 \cdot l \cdot (l_{WE} + h_{WE} - 2 \cdot l), \text{m}^2, \tag{7}$$

$$S_{\text{PROF.}} = 2 \cdot l_{PROF.} \cdot (l_{WE} + h_{WE} - 2 \cdot l - 2 \cdot l_{FF}),\ \text{m}^2, \tag{8}$$

$$S_{FF} = 2 \cdot l_{FF} \cdot (l_{WE} + h_{WE} - 2 \cdot l_{FF}),\ \text{m}^2, \tag{9}$$

$$\bar{s}_{GL} = 1 - \frac{i_{C.WE} + 1}{\sqrt{i_{C.WE}}} \cdot \frac{2 \cdot l}{\sqrt{S_{WE}}} + 4\frac{l^2}{S_{WE}},\ \text{relative units}, \tag{10}$$

$$\bar{s}_{FF} = \frac{i_{C.WE} + 1}{\sqrt{i_{C.WE}}} \cdot \frac{2 \cdot l_{FF}}{\sqrt{S_{WE}}} - 4\frac{l_{FF}^2}{S_{WE}},\ \text{relative units}, \tag{11}$$

$$\bar{s}_{\text{PROF.}} = \frac{2 \cdot l - 2 \cdot l_{FF}}{\sqrt{S_{WE}}} \cdot \frac{i_{C.WE} + 1}{\sqrt{i_{C.WE}}} + \frac{4 \cdot l_{FF}^2 - 4 \cdot l^2}{S_{WE}},\ \text{relative units}. \tag{12}$$

According to the formula (10), there has been determined the dependence of the relative area of glazing from window embrasure area for certain values of the relative width of the window embrasure.According to the data calculations, there has been constructed relevant graphs (fig. 4). The analysis of the graphs showed that the dependences of the glazing area of blank MPW from the window embrasure area is well described by logarithmic functions $y = a \cdot \ln(x) + b$ type apart from size $i_{C.WE}$. Especially intensive growth of the glazing area occurs in the initial section (0-A-0,75-0). Starting from point B the intensity of increasing of glazing area significantly decreasing, while the size and weight of the MPW significantly increasing. That is why the MPW sections 0,75-A-B-6 can be reputed the most likely for use from the practical point of view. Applying of MPW with window embrasure area less than 0,75 m^2 for any values $i_{C.WE}$ is irrational because the relative area of glazing becomes less than 0,5.

From the aesthetic point of view, the window embrasures, in a based construction of which fastened the symmetry of the golden section, should be preferred, not only because they occupy an average value between the minimum and maximum values (curve 3 on figure 4) according to the index of glare, but also because they call a feeling of beauty and harmony. According to formulas (7), (8), (9), there has been calculated dependences of the relative and absolute (formulas 10, 11, 12) areas of glazing, profile and foam filling from the relative width ($i_{C.WE}$) of the window embrasure for rectangular windows with an area of 6 m^2 (table 4 and 5) and 1 m^2 (table 6 and 7).

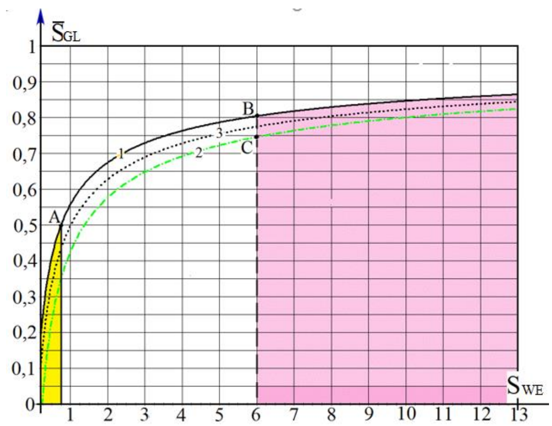

Figure 4. Dependence of the relative glazed area of blank window from the square of the window embrasure by the rectangular form for certain values of the coordination index: 1 – $i_{C.WE} = 1$; 2 – $i_{C.WE} = 3,25$; 3 – $i_{C.WE} = 1,614$ (golden ratio)

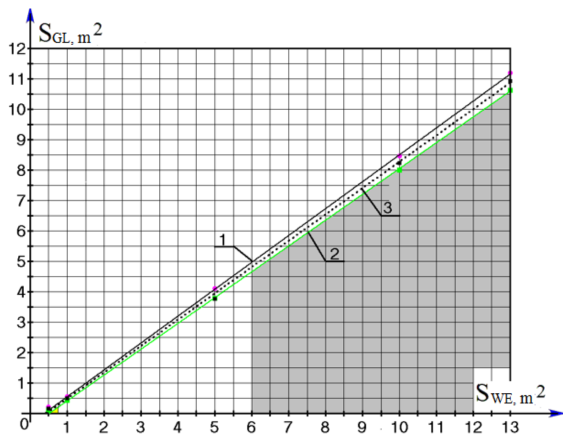

Figure 5. Dependence of the relative glazed area of blank window from the square of the window embrasure by the rectangular form for for certain values of the coordination index: 1 – $i_{C.WE} = 1$; 2 – $i_{C.WE} = 3,25$; 3 – $i_{C.WE} = 1,614$ (golden ratio)

Table 4

Relative area of glazing, profile and foam filling for a rectangular window embrazure by an area of 6 m^2, with a different value of window embrasure coordination index

Coordination index, WE $i_{C.WE}$	1/1	2/1	3/1	4/1	6/1	8/1	12/1	18/1	24/1
$\bar{S}_{GL}$	0,864	0,840	0,825	0,797	0,767	0,739	0,691	0,630	0,578
$\bar{S}_{PROF.}$	0,114	0,121	0,119	0,143	0,164	0,183	0,217	0,260	0,298
$\bar{S}_{FF}$	0,021	0,039	0,056	0,061	0,069	0,077	0,091	0,109	0,124

According to the tab.4 and 6 there has been constructed the corresponding graphic dependencies, presented on fig. 6. From fig. 6 is apparent that with an increasing of the relative width of the rectangular window embrasure, the area of glazing decreases (curves 1 and 4), and the area of the profile (curves 2 and 5) and the enthalpy (curves 3 and 6) increase. Herewith, decreasing rate of area glazing increases by a decreasing the area in the rectangular window embrasure. By the area of window embrasure of 1 m^2 with $i_{C.WE} = 24$ the area of glazing is equal zero.

Table 5

Area profile, foam filling and glazing for a rectangular window embrazure with an area of 6 m^2, with a different value of window embrasure coordination index, m^2

Coordination index, WE, $i_{C.WE}$	1/1	2/1	3/1	4/1	6/1	8/1	12/1	18/1	24/1
S_{GL}, m^2	5,187	5,04	4,95	4,78	4,60	4,44	4,15	3,78	3,47
$S_{PROF.}$, m^2	0,69	0,72	0,71	0,86	0,98	1,10	1,30	1,56	1,79
S_{FF}, m^2	0,13	0,24	0,34	0,36	0,42	0,46	0,55	0,65	0,75

Table 6

Relative area of glazing, profile and foam filling for a rectangular window embrazure by an area of 1 m^2, with a different value of window embrasure coordination index, m^2

Coordination index, WE, $i_{C.WE}$	1/1	2/1	3/1	4/1	6/1	8/1	12/1	18/1	24/1
$\overline{S}_{GL}$, relative units	0,695	0,672	0,637	0,600	0,529	0,461	0,330	0,140	0,00
$\overline{S}_{PROF.}$, relative units	0,265	0,282	0,309	0,336	0,387	0,433	0,514	0,616	0,706
$\overline{S}_{FF}$, relative units	0,041	0,046	0,054	0,063	0,083	0,106	0,156	0,243	0,303

Table 7

Area profile, foam filling and glazing for a rectangular window embrazure with an area of 1 m^2, with a different height-to-width aspect ratio, m^2

Coordination index, WE, $i_{C.WE}$	1/1	2/1	3/1	4/1	6/1	8/1	12/1	18/1	24/1
S_{GL}, m^2	0,695	0,67	0,64	0,60	0,53	0,46	0,33	0,14	0,00
$S_{PROF.}$, m^2	0,26	0,28	0,31	0,34	0,39	0,43	0,51	0,62	0,71
S_{FF}, m^2	0,04	0,05	0,05	0,06	0,08	0,11	0,16	0,24	0,30

Besides of the blank window constructions there has been considered multi-sectional MPW (three sectionals, in which the extreme sections are fixed, and the average moving), the general appearance of which is presented on fig.7. The relative area of glazing of a window embrasure with a multi-sectional light-transmitting structure was determined by the following formula derived by us.

$$\bar{s}_{GL} = 1 - \frac{i_{C.WE}+1}{\sqrt{i_{C.WE}}} \cdot \frac{2 \cdot l}{\sqrt{S_{WE}}} - \left(\frac{(h_{WE} - 2\cdot l)\cdot(l_{MBS}\cdot(2\cdot n_{BS} - 1) + n_{MS}\cdot(l_{MBS} - l_S))}{S_{WE}} + \frac{2\cdot l_S \cdot \sum_{i=1}^{i=n_{MS}} (l_{MSi} - l_{MMS} - 2\cdot l_S + h_{WE} - 2\cdot l) - 4\cdot l^2}{S_{WE}} \right). \qquad (13)$$

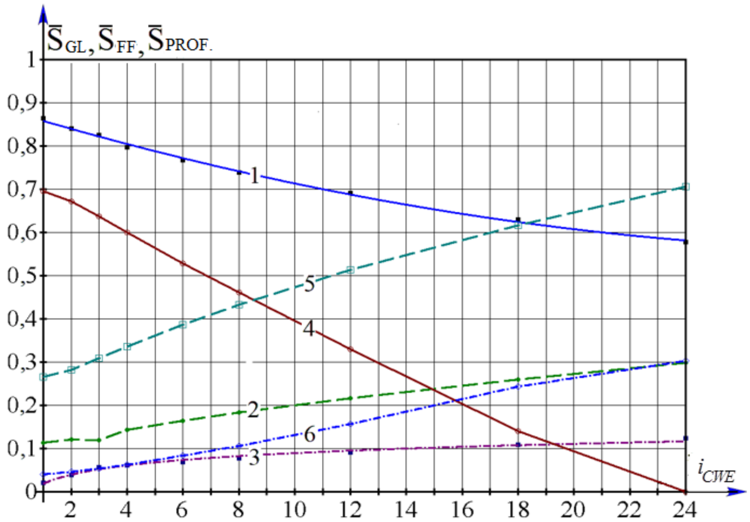

Figure 6. Dependenses of the relative areas of the glazing (curves 1 and 4), the profile (curves 2 and 5), and the foam filling (curves 3 and 6) for the blank window from the coordination index of the rectangular window embrazure by the area of: a) 6 m^2 – curves 1,2,3; b) 1 m^2 – curves 4,5,6, respectively

The results of calculations of relative areas of glazing, profile and foam filling for 3-sectional window rectangular embrasures with different values of $i_{C.WE}$ are given in table 8. According to the results of the table. 8 there has been constructed graphic dependencies, presented on a fig. 8. From a fig. 8 it is obvious that in multi-sectional MPW the area of land is the most acceptable, from a practical point of view for use, scoot aside in higher values - from 0,75-A-B-6 for blank windows to A-B-C-7. An additional point is that, the windows of the specified range became attractive not only from aesthetic point of view, but also in terms of glazing

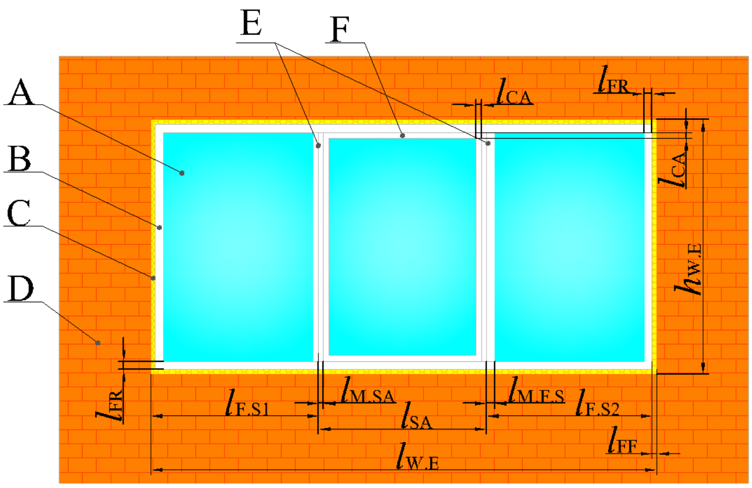

Figure 7. General view of three sectional MPW

Instrumentation symbols:
A – glazing;
B – frame;
C – foam filling;
D – building envelope;
E – muntin;
F – sash;
l_{MBS} – the thickness of the muntin blank section, m;
l_{MMS} – additional thickness of muntin, determined by the installation of a movable section, m;
l_S, l_F, l_{FF} – the thickness of the sash, frame and foam filling respectively, m;
l_{BSn}, l_{MSn} – width of the n-th blank and n-th moving sections, m

Table 8

Relative areas of glazing, profile and foam filling for rectangular window embrasure by using three sectional MPWs of different sizes from $i_{C.WE}$ =1; 1,618; 3,25 relative units

	Window embrasure area, m^2								
	1	2	3	5	7	9	11	12	13
3,25/1									
$\overline{S}_{GL}$, rel. un.	0,448	0,581	0,642	0,704	0,740	0,768	0,789	0,798	0,805
$\overline{S}_{PROF.}$, rel. un.	0,495	0,369	0,308	0,243	0,207	0,185	0,168	0,162	0,156
$\overline{S}_{FF}$, rel. un.	0,057	0,050	0,050	0,053	0,053	0,047	0,042	0,041	0,039
	Window embrasure area, m^2								
	1	2	3	5	7	9	11	12	13
1,618/1									
$\overline{S}_{GL}$, rel. un.	0,441	0,581	0,648	0,716	0,753	0,776	0,792	0,799	0,805
$\overline{S}_{PROF.}$, rel. un.	0,515	0,384	0,320	0,253	0,216	0,192	0,174	0,167	0,161
$\overline{S}_{FF}$, rel. un.	0,044	0,035	0,032	0,031	0,031	0,032	0,034	0,034	0,034
1/1									
$\overline{S}_{GL}$, rel. un.	0,388	0,545	0,620	0,697	0,738	0,765	0,784	0,792	0,799
$\overline{S}_{PROF.}$, rel. un.	0,571	0,424	0,353	0,279	0,238	0,211	0,192	0,184	0,177
$\overline{S}_{FF}$, rel. un.	0,041	0,031	0,027	0,024	0,024	0,024	0,024	0,024	0,024

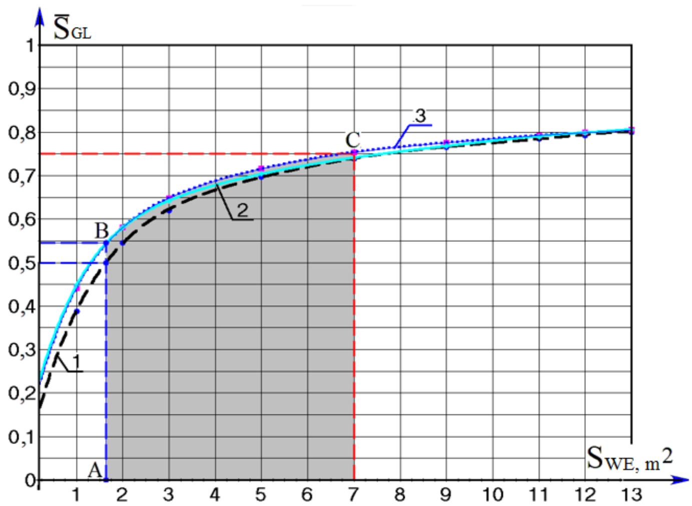

Figure 8. Dependence of relative glazed areas of the rectangular window embrasure with the use of three sectional MPWs by various sizes with $i_{C.WE}$ = 1; 1,618; 3,25 relative units

Conclusions.

1. The calculations confirmed that the glazing of window embrasure weakly depends from their configuration and smoothly decreasing in the direction from the illuminators to the square, rectangular and triangular forms, which made it possible (with taking into account the cost of manufacturing) as the main configuration to choose a rectangular.

2. It has been obtained the analytical expressions for determining the relative and absolute values of the glazing, profile and foam filling of window embrasure of a rectangular shape with any predetermined relative width of the window embrasure, which makes it possible to determine the optimal, in terms of glazing, the size of window embrasure

3. It has been found out that in the linear proportional growth of the square rectangular

window embrasure ($i_{C.WE} = \text{const}$) its perimeter, relative to the perimeter of 1 m^2, grows as the square root of its area. That is, it grows much slower than the area of the window embrasure. That is why the increaseing of the glazing area is increased due to the growth of the window embrasure area.

4. It has been proved that, from the aesthetic point of view, window embrasure, on which based the symmetry of the golden section, should be preferred, not only because they occupy an average value between the minimum and maximum values (curve 3 in figure 4) according to the index of glare, but because they call a sense of beauty and harmony.

5. It has been proved that only dependencies of the relative areas of glazing from the areas of the window embrasure can be realized with an acceptable range of dimensions of the MPW in terms of ensuring high natural lighting of premises.

6. It has been established that in multi-sectional MPWs the glazing area is always smaller than that of the blank window (see figures 4 and 8) due to the addition of their movable wings, which indicates on the expediency of rejecting from traditional small ventilating window and the necessity of their number limiting sufficient to maintaining of double-glazed windows high transparency

The prospect of the further researches is the determination of the optimal areas of glazing and the location of window embrasures for rooms by arbitrary dimensions and orientation, not only in terms of increasing the proportion of natural light, but also for the creating of comfortable living conditions regardless to the season.

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ЗАЛЕЖНОСТІ ВІДНОСНОЇ ТА АБСОЛЮТНОЇ ПЛОЩ ЗАСКЛЕННЯ ВІД КОНФІГУРАЦІЇ ТА ЗАГАЛЬНОЇ ПЛОЩІ ВІКОННОГО ПРОРІЗУ

Микола Тарасенко; Віталій Бурмака; Катерина Козак

Тернопільський національний технічний університет імені Івана Пулюя, Тернопіль, Україна

Резюме. *Висвітлено питання економії електричної енергії, яка витрачається на освітлення приміщень, за рахунок збільшення частки природного свтла. В результаті досліджень отримано аналітичні вирази для визначення абсолютних і відносних площ засклення віконних прорізів довільної конфігурації. Це дало можливість (при урахуванні вартості виготовлення) в якості основної конфігурації вибрати прямокутну. Доведено, що тільки з залежностей відносних площ засклення від площ віконного прорізу можна визаначитися з прийнятним діапазоном розмірів металоплатикових вікон з точки зору забезпечення високої природної освітленості приміщень.*

Ключові слова*: засклення, профіль, вікно, відносна площа, відносна ширина віконного прорізу, природне освітлення, запінення, склопакет, форма вікна.*

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