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DEFINITION OF A COMPOSITE INDEX OF GLAZING ROOMS

V. Burmaka
Postgraduate student*
E-mail: vitaliy.burmaka@gmail.com
M. Tarasenko
Doctor of Technical Sciences, Professor, Head of Department*
E-mail: tarasenko_mykola@ukr.net
K. Kozak
PhD, Senior Lecturer*
E-mail: kozakateryna@gmail.com
V. Khomyshyn
Postgraduate student*
E-mail: homyshyn@gmail.com
*Department of electrical engineering
Ternopil Ivan Puluj Technical University
Ruska str., 56, Ternopil, Ukraine, 46001

Розглянуто вплив геометричних параметрів приміщень та віконних прорізів на величину коефіцієнта природного освітлення (КПО) в розрахунковій точці на робочій поверхні. Це важливо, тому що при використанні window-to-floor ratio та window-to-wall ratio спостерігається значна похибка. Тому існують об'єктивні труднощі з уніфікацією результатів досліджень ефективності бокового природного освітлення, які обумовлені впливом розмірів приміщення на значення КПО в розрахунковій точці на робочій поверхні.

Використання вищезгаданих коефіцієнтів для оцінки ефективності бокового природного освітлення призводить до того, що при сталому значення коефіцієнта, величина КПО може відрізнятися в декілька раз. Це зумовлено тим, що площа віконного прорізу не відповідає площі засклення, через яке денне світло проходить в середину приміщення. Площа приміщення не відповідає площі робочої поверхні, на якій потрібно забезпечити нормовану освітленість, а розміри як приміщення, так і робочої поверхні, взагалі не враховуються ні в WWR, ні в WFR.

Запропоновано використовувати зведений індекс засклення приміщення (ЗІЗП). Він враховує не тільки площу засклення віконного прорізу, але й розміри та площу робочої поверхні. Це дає можливість використовувати результати досліджень ефективності природного освітлення без прив'язки до конкретних розмірів приміщення. За допомогою програми Relux розраховано значення КПО в розрахунковій точці для приміщень різних розмірів з різною площею засклення віконного прорізу і отримано залежність КПО від ЗІЗП. В результаті апроксимації даної залежності отримано рівняння, яке описує взаємозв'язок між даними величинами.

Для визначення площі віконного прорізу, при якій буде забезпечено необхідне значення КПО в розрахунковій точці, розроблено алгоритм, який враховує як ширину непрозорої частини віконного прорізу, так і його пропорції. Отриманий науковий результат у вигляді ЗІЗП та алгоритму розрахунку площі віконного прорізу є цікавим з теоретичної точки зору. З практичної точки зору отримані результати дозволяють розраховувати мінімальну площу засклення віконного прорізу для забезпечення нормованого значення КПО з стандартним відхиленням 0,894, спираючись виключно на розміри приміщення. Це складає передумови для використання отриманих результатів при розробці будівельних нормативних документів

Ключові слова: віконний проріз, природне освітлення, коефіцієнт природного освітлення, зведений індекс засклення приміщення

1. Introduction

At present, while addressing the issue of lighting buildings, attention is focused on the use of artificial light sources, which, according to the International Energy Agency, make up about 19 % of the world's total energy consumption. Electrical lighting of rooms still prevails in creating light space. In many buildings, natural light is barely noticeable, even on the most clear and sunny days. Effective norms of natural lighting of buildings are available only in European countries. In the EU, natural lighting is obligatory only in Slovakia and the Czech Republic.

And this at a time when it is possible to design buildings filled with sunlight, which provides not only visual comfort and health effects on the person but also guarantees the economy of electricity. The sun has a solid spectrum of radiation and the best colour reproduction. The colour temperature of its radiation varies from 6,000 K at noon to 1,800 K at dawn and at sunset. Under normal conditions, artificial lighting in rooms is much lower than natural lighting, even in the gloomiest weather. For example, the levels of horizontal illumination in rooms without daylight are within 100–500 lux. Natural light even on the darkest day is at a level from 1,000 to 2,000 lux or more. In a clear sunny morning, this figure in the open air rises to 100,000 lux.

The most common way of introducing sunlight into a room is to use a lateral lighting system. Therefore, studying the parameters that affect the efficiency of natural sidelight, especially on the background of the total use of modern energy-efficient windows, remains important.

Nowadays, there are problems of how to unify recommendations regarding the area of a window opening (WO) to ensure maximum efficiency of natural light in rooms of arbitrary dimensions. This is due to the fact that the use of the window-to-floor ratio (WFR) and the window-to-wall ratio (WWR), in comparison with the effectiveness of natural light, leads to significant errors. They are caused by the influence of the size of rooms on the daylight factor value and the fact that, when using these factors, the area of the opaque parts of the window sill and the areas of the rooms where the normalized illumination are not required to be taken into account. Against this background, tests on determining the effect of individual geometric parameters of buildings and WOs on the value of the daylight factor (DF) and on the search for a composite room glazing index (CRGI) are essential.

2. Literature review and problem statement

According to [1], the use of daylight helps save up to 2/3 of electric energy by reducing the cost of artificial lighting. The data were obtained on the layout of a room reduced 50 times to specific dimensions. For rooms with other dimensions, the results obtained cannot be applied.

In [2], heat loss studies were conducted for a WO and electricity consumption to remove the heat that enters it. However, the definition of the optimal area of a WO, in terms of daylight, for office space, remains unconsidered. In [3], the optimal value of the WFR for several rooms of different shapes and areas was investigated. The disadvantage of the results is that for the rooms of different sizes, the optimal value of the WFR is different, that is, the results obtained are valid only for the same rooms that were selected for the research. In [4], the study concerned the effectiveness of using natural lighting of academic rooms. However, because there is no value that allows comparing the DFs of rooms of different sizes, the results of these studies can be used only for specific cases.

In [5], it is argued that the area beyond 6 m from a window can only be considered as "partially lit" by natural light, that is, it requires additional artificial lighting for a long time. However, attention is not paid to the effect of the width of the room on the level of daylight.

In [6], it is emphasized that in relation of the height of the room to its width of 1:1, the energy efficiency of using natural light is lower than that in the same area but with a proportion of 1:3. The difference in energy consumption is 15 % of the total energy use for lighting. At the same time, the dependence of the DF on the size of the rooms is not considered.

In [7], the dependence of the DF on the relative area of the WO in the external enclosing structure (EES) in which it was installed was established. It has been determined that the optimum area is within the limits of 20–40 %. However, the proportions of the WO were not taken into account. Paper [8] also considered issues regarding the effectiveness of natural light, but, as in the other cases, only certain dimensions of both WOs and rooms were selected. Although according to [9] they have a significant effect on the DF value in the reference point (RP) on the work surface (WS).

Neither the optimal depth of the room nor the relative area of the WO in the EES was specific in the studies; they were set just as a range of values. In this case, the depth of the rooms was not the same for all studies, and the relative area of the WOs was in a large interval of values. This is the basis for conducting studies related to determining the value at which the same values of the DF in rooms of different sizes with different glazing areas will be provided.

It is worth noting that in 2006 the scientific community came to the conclusion that the methods of determining the DF value, which are given in DBN B.2.5-28-2006, are obsolete [10, 11]. A large number of free, high-precision programs for calculating natural light have been developed at present; their validity was verified by real measurements in [12, 13]. The calculation of the DF values given in this article was carried out using the Relux program.

3. The aim and objectives of the study

The aim of the study is to determine the parameter that would help unify the results of researching natural lighting of rooms of different sizes. From a practical point of view, the result will determine the area of the WO with which the standardized value of the DF will be provided using only the size of the room.

To achieve this aim, the following objectives were solved:

– to determine the dependence of the standardized value of the DF on the size of the room, its area and proportions of the WO;

– to estimate the expediency of using the relations of the WO area to the internal area of the enclosing structure (ES) in which it is installed (S_{WO}/S_{ES}) and of the WO area to the area of the room (S_{WO}/S_{R}) in the study of the effectiveness of natural lighting in rooms of different sizes;

– to study the possibility of determining the area of a single-section WO at which the normalized value of the DF can be ensured, using only the dimensions of the room.

4. Materials and methods of studying the influence of the room size as well as the area and proportions of window openings on the value of the DF

4. 1. Methodology for determining the reference point when calculating the DF

At the beginning of the tests on the impact of the room size and the WO on the value of the DF, it is necessary to determine the requirements and rules for its calculation. In accordance with the current normative document DBN V.2.5-28-2006, there are two options for selecting the RP: 1 – in the most remote point of the WS from the middle of the WO; 2 – in the middle of the room at a distance of 1 m from the wall opposite to the WO. The second option may lead to non-compliance with the regulatory requirements because, when choosing a typical section located in the middle of the room, the width of the room has little impact on the DF value in the RP. That is, the existing definition of a typical section of a building is controversial in the requirements. It is also necessary for it to be placed in the middle of the room so that it could include areas with the largest number of workplaces and workstation points, the most distant from the WO. Taking into account the above-mentioned observations for lateral illumination, the following definition is proposed. A typical section of a room is a section A-A whose plane is perpendicular to the plane of the WO and passes through the most remote point of the work surface C from the centre of the light slot (Fig. 1).

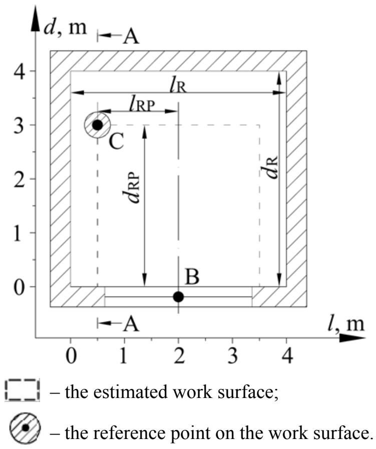

Fig. 1. The scheme of a room 4×4 m in size and with a WO area of 6 m^2

Fig. 1 includes the following designations: A-A – the plane of the characteristic section of the room for calculating the DF; d_R – the depth of the room, m; l_R – the width of the room, m; d_{RP} – the depth of the reference point, m; d_{RP} – the distance from the axis of symmetry of the WO to the reference point, m.

4. 2. Test materials and means used in the research

According to DBN B.2.5-28-2006, which complies with European standards DIN EN 12464-1:2011-08, extra natural lighting is standardized with the minimum values of the DF. Therefore, the RP for determining it is selected in the most remote point of the WS, which is located at a distance of 1 m from the wall opposite to the WO.

For research purposes, rooms were chosen with the following dimensions (width×depth): 4×4 m (Fig. 1); 4×5 m; 4×6 m; 4×7 m; 5×4 m; 5×5 m; 5×6 m; 5×7 m; 6×4 m; 6×5 m; 6×6 m; 6×7 m; 7×4 m; 7×5 m; 7×6 m; 7×7 m; 8×4 m; 8×5 m; 8×6 m; 8×7 m; and the heights

a) room h_R=3 m;

b) the work surface h_{WS}=0.8 m.

The location of the WO affects the DF value due to the different brightness of a cloudy sky, according to DBN V.2.5-28-2006 (DIN EN 12464-1:2011-08). Therefore, the centres of the weights of the selected WOs were registered in one point W, which is located in the centre of the EES site, above the level of the WS (h_{WS}) (Fig. 2).

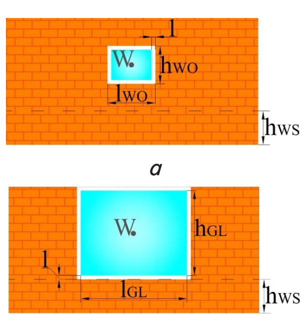

Fig. 2. The appearance of the enclosing structure with a rectangular window opening area: *a* – 1 m^2; *b* – 6 m^2

The area of all treated WOs varied from the minimum possible, recommended by DSTU B B.2.6-23:2009 (ISO 21930), the value of S_{WOmax}=0.12 m^2, up to the maximum permissible S_{WOmax}=6 m^2, for a single-section blind, light-transmitting external enclosing structure (LTEES). The proportions of the WO were determined by the accepted dimensions: the height of the room – h_R=3 m, the height of the work surface – h_{WS}=0.8 m, and the maximum area of the LTEES, with the expressions: width

$$l_{WO}=S_{WOmax}/(h_R-h_{WS})=6/(3-0.8)=2.73 \text{ m};$$

height

$$h_{WO}=S_{WOmax}/l_{WO}=6/2.73=2.2 \text{ m}.$$

Thus, all the WOs considered had the proportions of (l_{WO}/h_{WO}):2.73/2.2.

5. Results of studying the influence of geometric dimensions of rooms and WOs on the value of the DF

According to [14], the area of the glazing, profile and foaming of the WO of a rectangular shape of different areas, with a width/height ratio of 2.73/2.2 was calculated. The calculations were made for rooms the parameters of which comply with the requirements of the current normative documents of Ukraine: DBN V.2.5-28-2006 (DIN EN 12464-1:2011-08), DSTU B V.2.6-23:2009 (ISO 21930), and DBN V.2.6-31:2016 (ISO 91.120.10). According to them, the selected values of the height of the room, the thickness of its walls, and the reflection coefficient of the interior surfaces of the enclosing structures (Table 1).

Table 1

The estimated parameters of the rooms

Parameter	Height, m	Thickness of the walls, m	Coefficients of ceiling/wall/floor reflection, rel. units
Value	3	0.38	0.7/0.5/0.2

For research purposes, the PROLINE profile was selected with a single-section glass pane of 4–16–4, which has the highest transmittance of solar radiation (0.8). According to the above data, Relux program calculated the value of the DF in the RP for rooms of selected sizes with the parameters given in Table 1. WOs with an area of 0.12–6 m^2 were considered, and the thickness of the non-transparent part was calculated in accordance with [14]. The DF was calculated according to the algorithm for determining global illumination (Radiosity). The error in calculating the DF by this algorithm is 7 % [15]. Based on the results of the calculations, corresponding graphic dependencies were constructed; they are presented in Fig. 3.

Fig. 3 shows that with the same area of rooms of 20 m^2 (4×5 and 5×4) with a WO area of 6 m^2, the values of the DF differ 1.387 times (Fig. 3, pts. A and B). With the increase in the width of a room with an area of 3 m^2, 1 m (from 5×4 (20 m^2) to 6×4 (24 m^2)), the value of the DF decreases 1.03 times (Fig. 3, pts. C and D). While with an increase in depth by 1 m (from 6×4 to 6×5), in order to provide the value of the DF by a maximum of 1.026 times, it is necessary to increase the area of the WO by 2 m^2 (Fig. 3, section D-E). Thus, in order to compare the DF values of rooms of different sizes, it is necessary to consider not only their areas but also their geometric sizes.

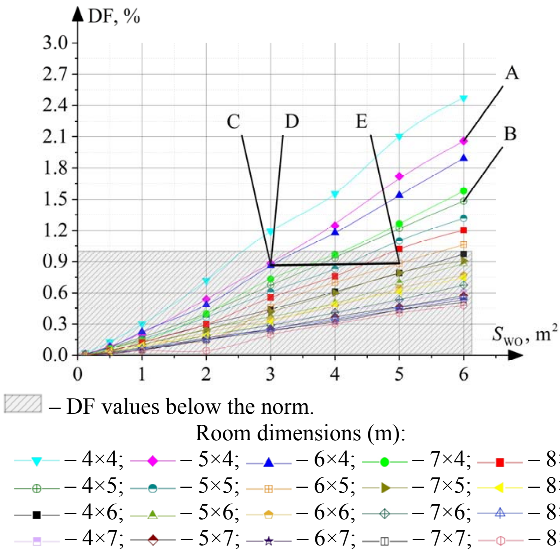

Fig. 3. The dependence of the DF on the area of the WO for rooms of different sizes

In studies [1, 2, 4, 6–9], the window-to-wall ratio (WWR), that is, the ratio of the WO area (S_{WO}) to the internal area of the enclosing structure S_{ES} in which it was installed was used to generalize the results. As can be seen from Fig. 4, *a*, for different sizes of rooms, the DF values become different with the same value of the WWR. Therefore, in terms of providing a standardized DF, the WWR cannot correctly characterize the required area of glazing or the WO. In eastern European countries, such as Ukraine, Belarus, Russia, etc., the light factor (LF) is defined as the ratio of the area of the WO to the floor area of the room (S_R). In English literature, the LF is referred to as the window-to-floor ratio (WFR).

To construct graphic dependencies (Fig. 4), the study uses the data obtained in determining the dependence of the DF in the RP on the area of the WO in the EES (Fig. 3).

As can be seen from Fig. 4, in both cases the graphs are similar. However, the WFR (Fig. 4, *b*) is more appropriate to use to compare the effectiveness of natural light since it takes into account not only the area of the WO but also the area of the room. In turn, the WWR is more appropriate to use for comparing the thermal insulation properties of the WO because it takes into account only the relative area of the WO in the EES. When comparing the values of the DF with the same values of the WFR for rooms of different sizes, the data may differ several times. The reason for this is the lack of parameters that would take into account the width and depth of a room as integral parts. This indicates the feasibility of studying the effect of room size on the change in the value of the DF in the RP.

In accordance with [9], the proportions of the WO affect the value of the DF in the RP, so it is worth checking whether the DF varies depending on the proportions of the WO in rooms of different sizes. For this purpose, rooms of 6×5 m and 4×5 m, with a WO area of 2 m^2 and with parameters of Table 1 were investigated. The ratio of the height to the width of the WO (Fig. 5, *a*) and the width to the height of the WO (Fig. 5, *b*) varied from 1 to 4, in step 0.1. DF calculations were carried out in the Relux program. In accordance with Fig. 5, with the same area and proportions of the WO, the DF varies in different ways in rooms of different sizes. This is explained by the fact that when the size is changed, the location of the RP relative to the WO is shifted.

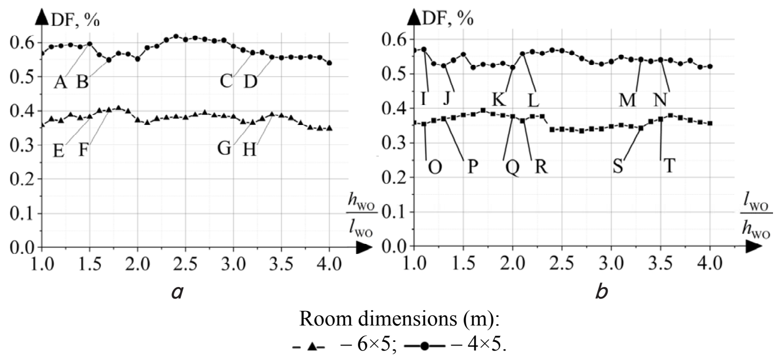

Fig. 5. The dependence of the DF value on the ratio of: *a* — the WO height to the width; *b* — the WO width to the height in rooms of different sizes, with the WO area of 2 m^2

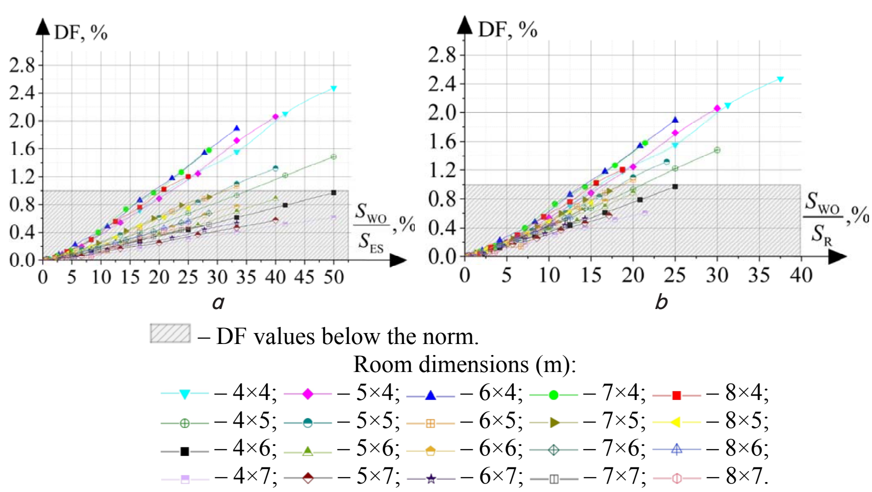

Fig. 4. The dependence of the DF value on: *a* — the WWR (S_{WO}/S_{ES}); *b* — the WFR (S_{WO}/S_R)

When changing the proportions of the WO, the DF value for a room of 4×5 m decreases (Fig. 5, *a*, section A-B), and for a room of 6×5 m, in the same range of proportions, it increases (Fig. 5, *a*, section E-F). In Fig. 5, *a*, *b* in the sections C-D, I-J, M-N, Q-R, and S-T, the DF decreases, and in the sections G-H, O-P, K-L, and S-T, it increases. This indicates that for different sizes of rooms, the nature of the change of the DF relative to the proportions is not synchronous.

As can be seen from Fig. 4, the use of the WFR does not help compare rooms of different sizes by the value of the DF. However, this coefficient takes into account the area of the room, so it was taken for further analysis.

Since the light-transmitting element of the WO is glazing, instead of the area of the WO it is more correct to take into account the area of the WO glazing (S_{GL}) [14]. The standardized value of the DF must be provided for the RP, but not on the entire area of the rooms (Fig. 1). Therefore, instead of the area of the room, it is more logical to take into account the area of the WS.

It should be borne in mind that the representation of the average sky is based on a number of assumptions. First, it is assumed that it is homogeneous, that is, cloudy, or clouds are distributed evenly throughout the sky. Secondly, it is considered isotropic, that is, it has the same physical properties in all directions. It is known that random cumulus clouds on a clear sky do not fit this assumption. However, given that the distribution of brightness in such cases is arbitrary, it makes no sense to consider it separately [16]. From the foregoing, it can be concluded that the distribution of the DF on the WS in width of the room is symmetric with respect to the axis of symmetry of the WO. Therefore, the area of the WS can be defined as a double product of the depth of the RP (d_{RP}) at a distance from the axis of symmetry of the WO to the RP (l_{RP}) ($S_{WS}=2\cdot d_{RP}\cdot l_{RP}$) (Fig. 1).

Natural light is normalized by the smallest value of the DF on the WS, which, as a rule, at designing corresponds to the value in the most remote point of the WS, which is taken as a RP. This means that with an asymmetric WS on a site that is located at a lesser distance from the WO, there will be a DF larger than in the RP. Therefore, the analysis must take into account the most remote point of the work surface (Fig. 1, pt. C) from the centre of the WO (Fig. 1, pt. B).

From the foregoing assertions, it is expedient to use the S_{GL}/S_{WS} ratio instead of the WFR. To reduce the calculation error, it is necessary to take into account not only the glazing area and the WS but also the size of the WS. For this, the S_{GL}/S_{WS} ratio is multiplied by the function of the index of coordination of the WS (1):

$$f(i_{C.WS}) = f(2\cdot l_{RP} / d_{RP}). \quad (1)$$

In the search for the function of equation (1), which could provide the necessary accuracy of calculations, the study of power, index and logarithmic functional dependences of $i_{C.WS}$ was carried out. Since the area of the WS and the index of coordination of the WS at multiplication lead to a decrease in its width ($k\cdot S_{GL}/d^2_{RI}$) or depth ($k\cdot S_{GL}/(4\cdot l^2_{RP})$), linear and hyperbolic functions were not considered.

The analysis showed that the power dependence $i_{C.WS}$ helps reduce the calculation error. In order to determine the degree at which all dependencies will change according to one law, rooms of different sizes and glazing areas were compared, and the DF values became close (the error up to 1 %). In accordance with Fig. 6, the total value of the power $i_{C.WS}$ (x) for rooms with dimensions of 6×5 m, 5×6 m, and 5×4 m, with the glazing areas of 4.24 m^2, 5.153 m^2, and 2.4333 m^2, and the DF values of 0.88831 %, 0.8834 % and 0.8839 %, respectively, were within the range of 0.230–0.264 (Fig. 6, pts. A_1, A_2, and A_3).

To construct graphic dependencies (Fig. 6), equations were used that describe the dependence of the value of the composite room glazing index (CRGI) on x for the above-mentioned cases. The general view of the equations is $I_{GL.R}=S_{GL}/S_{WO}\cdot i^x_{C.WS}$.

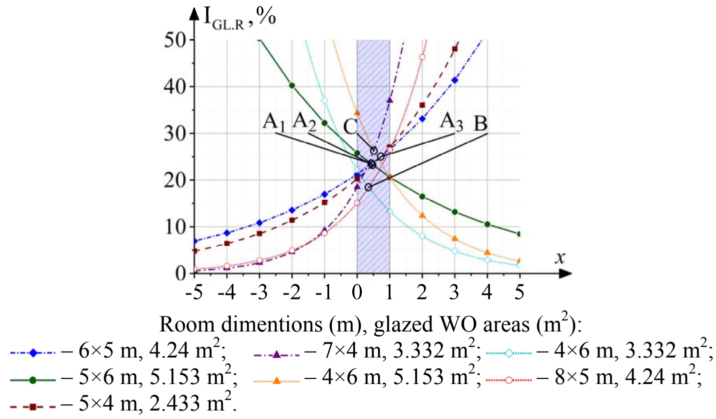

Fig. 6. The dependence of the CRGI on the power of the $i_{C.WS}$ (x)

For the considered variants with the same DF values, their common value of x is in the range from 0 to 1 (Fig. 6, pts. A_1, A_2, A_3, B, and C). Since the graphs intersect at different points, x also needs to vary depending on the size of the room. Therefore, as x, the sizes of the WS are $1/(2\cdot l_{RP})$, $1/(d_{RP})$, and $1/l_{RP}$. The ratio of $2\cdot l_{RPT}/d_{RP}$ and its inverse were not considered because the value of x was beyond the range indicated above. After comparing the obtained results, it has been established that only the use of the $1/l_{RP}$ ratio allows comparing the results of calculating the DF value for rooms of different sizes with a value range of less than 0.244 % (Fig. 7, pts. A and B).

To construct the graphical dependence of the DF on the CRGI (Fig. 7), the data obtained in determining the dependence of the DF in the RP on the area of the WO in the EES (Fig. 3) were used.

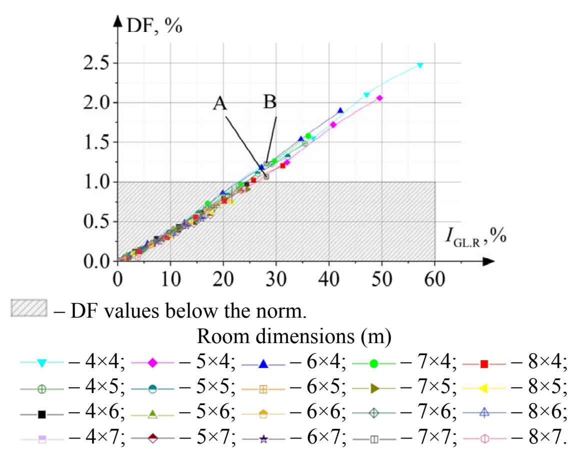

Fig. 7. The dependence of the DF value on the CRGI

As a result of considering WFR comments and using the power function for expression (1) with the power of $1/l_{RP}$, expression (2) was received for the CRGI. The obtained dependence takes into account not only the influence of the glazing areas of the WO and the WS but also the geometric dimensions of the WS on the size of the DF in the RP.

$$I_{GL.R} = S_{GL} / S_{WS} \cdot \sqrt[l_{RP}]{2\cdot l_{RP} / d_{RP}} \cdot 100, \%. \quad (2)$$

As a result of approximating the obtained point data (Fig. 7) by the least squares method, expression (3) was received, which helped determine the value of the CRGI for arbitrary values of the DF with a standard deviation of 0.894 and a determination coefficient of 0.994. Approximation was carried out using Advanced Grapher. To compensate for the deviations of the DF values relative to the CRGI due to the non-synchronous nature of the change of the DF relative to the proportions of the WO, we introduced the stock factor (4).

$$I_{GL.R} = -2{,}148 \cdot DF^2 + 27{,}087 \cdot DF + 0{,}487, \%, \quad (3)$$

$$I_{GL.R} = 1{,}1 \cdot (-2{,}148 \cdot DF^2 + 27{,}087 \cdot DF + 0{,}487), \%, \quad (4)$$

where 1.1 is the stock factor.

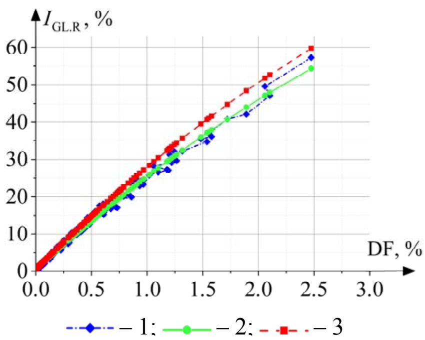

Fig. 8. The dependence of the CRGI on the DF values obtained as a result of: 1 — calculations in the Relux program; 2 — approximations (3); 3 — approximations taking into account the stock factor (4)

To compare the accuracy of the results of calculating the dependencies of the CRGI value on the DF values obtained in the Relux program as well as expressions (3) and (4), the corresponding graphs were constructed (Fig. 8). The analysis of the obtained graphs has shown that the use of the stock factor in calculating the CRGI simplifies the definition of the minimum glazing area because it can be neglected by the effect of shifting the RP on the WS by the value of the DF.

That is, the definition of the area of glazing the WO required for providing a normalized DF on the WS is reduced to expression (5):

$$S_{GL} = I_{GL.R} \cdot S_{WS} \cdot \sqrt[l_{RP}]{d_{RP} / (2 \cdot l_{RP})} / 100, \text{ m}^2. \quad (5)$$

In order to determine the area of the WO from the obtained value of the CRGI, in accordance with [14], it is necessary to use the WO Coordination Index ($i_{C.WO}$) (6)

$$i_{C.WO} = l_{WO} / h_{WO}, \text{ rel. units.} \quad (6)$$

Based on the selected proportions, the width (7) and the height (8) of the WO glazing were determined:

$$h_{GL} = \sqrt{S_{GL} / i_{C.WO}}, \text{ m}; \quad (7)$$

$$l_{GL} = \sqrt{S_{GL} \cdot i_{C.WO}}, \text{ m}. \quad (8)$$

In accordance with the obtained values in (7) and (8), for the selected proportions and profile width of a single-section WO, its area was determined, able to ensure the standardized DF (9):

$$S_{WO} = S_{GL} + 2 \cdot l \cdot (l_{GL} + h_{GL} + 2 \cdot l), \text{ m}^2, \quad (9)$$

where l is the width of the opaque part of the WO, m [14].

6. Discussion of the results of studying the influence of the width and length of a room and the WO proportions on the DF

As a result of the research, it was found that the size of a room has a significant impact on the size of the DF. Even with the same area of rooms, DF values can vary significantly from one another. For example, according to Fig. 3, pts. A and B, at an area of 20 m^2, depending on the size of the room, the DF varies from 1.48 % at a width of 4 m and a depth of 5 m to 2.06 % at a width of 5 m and a depth of 4 m. This indicates that the use of the WFR is not correct because with the same values of the WFR, the value of the DF may differ 1.388 times.

The use of the WWR also does not allow comparing the energy efficiency of natural lighting in rooms of different sizes. For example, for a room with a width of 4 m and with a WWR value of 50 %, the change in the depth of the room leads to a change in the DF from 2.47 % at 4 m to 0.61 % with an increase in depth to 7 m. That is, with the same meaning of the WWR, the DF decreases 4 times.

The use of the CRGI helps determine the minimum area of the WO to provide the normalized illumination in the RP of the WS. The obtained results can be used by specialists of light engineering and construction industries in the design of natural side lighting.

However, it is noteworthy that the results of the study (Fig. 5) indicate an ambiguous influence of the WO proportions on the DF value for rooms of different sizes. It should also be noted that the research results are reliable only for non-shadowed rooms without sunscreen devices. Such uncertainty imposes limitations on using the obtained results, which can be interpreted as the disadvantages of this study. Failure to take into account these parameters in the framework of the study indicates the need to research further the effects of sunscreen devices not only on the value of the DF but also on the energy efficiency of side lighting in general.

7. Conclusion

1. It has been proven that with the same area of a room, the DF value when changing its size may vary 1.388 times (Fig. 3). This indicates the incorrect use of the WFR to standardize the minimum area of glazing in rooms of different sizes. With different room sizes, the nature of the change of the DF relative to the proportions is not synchronous. As can be seen from Fig. 5, on the same intervals of the proportions and with the same sizes of rooms, the DF increases, whereas in other cases it decreases.

2. It has been established that the use of not only the WWR but also the WFR for comparing the natural lighting of rooms of different sizes is inadmissible. This is due to the fact that, with their fixed values, the DF value can differ 4 times in the first case and 2 in the second, depending on the size of the room.

3. An expression for the consolidated index of the glazing of a room is obtained, which makes it possible to determine the area of the WO at which the normalized value of the DF is provided without being tied to certain dimensions of the room. This expression takes into account the area of glazing the WO, the WS area, as well as the depth and width of the room. An algorithm for calculating the window sill area has been developed to provide a normalized DF value in non-shadowed rooms of arbitrary dimensions. This algorithm allows determining the area of a single-section WO at which the normalized value of the DF in the RP and, consequently, throughout the WS will be ensured.

4. It has been proven that for different sizes of rooms, the nature of the DF change relative to proportions is not synchronous. As can be seen from the obtained results, on the same intervals of proportions and with the same sizes of rooms, the DF increases, whereas in other cases it decreases.

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