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CHANGES IN LIGHTING STANDARDS AND THEIR INFLUENCE ON THE ARCHITECTURE AND ENERGY EFFICIENCY OF MODERN RESIDENTIAL BUILDINGS

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Abstract. State regulations on the design of lighting in residential buildings in recent years have undergone significant changes, which in turn will significantly affect the architecture and energy efficiency of modern buildings of this type. This can be observed from the authors' analysis of the change in only one regulatory document given in this article – SCS (State Construction Standards) V.2.5-28: «Natural and artificial lighting» and only one lighting indicator: permissible deviation of the calculated value of CNL (coefficient of natural lighting) from the standardized value when choosing translucent structures of buildings. This article presents an analysis of this normative document in two versions – in the old one from 2012 and new from 2018. Based on the results of the analysis, the authors of this article found that, at the request of the architect, the area of translucent structures on the facades of two identical modern residential buildings can differ significantly: from the minimum with piece (separate) windows on the facades – where glazing occupies from 14.3% to 18.3% of the area of the facades; up to maximum with continuous glazing of facades – where glazing occupies up to 100% of the area of the facades of a residential building. These two facade glazing options are not only architecturally perceived differently, but they must also have different energy efficiency in order to provide different minimum allowable values of heat transfer resistance: for piece (individual) windows on the facade, this is $R_{\Sigma} \geq R_{q\ min} = 0.6\ m^2 \cdot K/W$ and ordinary silicate glasses are suitable for their glazing, and for continuous glazing of the facade this should already be $R_{\Sigma} \geq R_{q\ min} = 2.8\ m^2 \cdot K/W$, that is, they must have the same heat-shielding properties as the outer walls, and their minimum allowable value of the heat transfer resistance must be 4.66 times more than for piece (separate) windows. For this option, ordinary silicate glass is no longer suitable, but modern glass-transparent structures with high heat-shielding properties should be used, for example Qbiss_Air, Pilkington, Heat Mirror Glass and others. They provide excellent protection against hypothermia in winter and overheating in summer, and have good sun protection properties. Their use in modern buildings contributes to energy savings for heating and cooling rooms throughout the year and creates increased comfort, but such translucent structures are much more expensive and better suited for elite housing construction than for social.

Keywords: lighting standards, energy efficiency of buildings, natural lighting, and translucent building structures.

Introduction. SCS (State Construction Standards) change constantly and their implementation can significantly affect various indicators of the buildings designed for different purposes, including their energy efficiency. Thus, till 2018, to solve the problem of a choice of translucent constructions of houses of different function (including residential), SCS V.2.5-28:2006 «Natural and Artificial Lighting» Zmina №2. K.: Minrehion Ukrayiny, 2012 [1] were used, while in 2018 they were replaced with a new regulatory document on construction lighting – SCS V.2.5-28:2018 «Natural and Artificial Lighting». K.: Minrehion Ukrayiny, 2018 [2] (commenced in 2019). These regulatory documents have many differences, but this article considers only one of them – the change of the allowable deviation of the calculated value of CNL (coefficient of natural lighting) from the normalized (Appendix M, p. 121, [2]) when choosing translucent elements of buildings and analyzed how it affects the architecture and energy efficiency of modern residential buildings.

Analysis of recent research and publications. According to the old SCS V.2.5-28: 2012 – p. 31 [1], the deviation of the calculated value of CNL from the normalized value supposed to be within -5% ÷ + 10%, that is, when choosing the windows of residential buildings, it used to be permissible to limit the change in the area of translucent structures, both downwards and upwards.

According to the new SCS V.2.5-28: 2018 – p. 121 [2], the reduction of the calculated value of CNL from the normalized is by no more than 10%. So, when choosing windows of residential buildings now, it is permissible to limit the change in the area of translucent structures only downwards, while the increase in the area of translucent structures on the facades of modern residential buildings is not limited.

It should be noted that the norm-setting of natural lighting of residential buildings is also provided in another reference document – SCS V.2.2.-15:2019 "Residential buildings" [3] article 10.4 "…Living rooms, kitchens and other should have natural lighting. The ratio of the lighting aperture area of living rooms and kitchens to the floor area of these premises should be in the range from 1:5.5 to 1:8".

For example, if the floor area of a living room is $S_{floor} = 40m^2$, the area of its windows can be within $S_{window} = 4.27\ m^2 \div 5.5m^2$; if the wall area of this living room is equal to $S_{wall} = 10\times3(h) = 30m^2$, it must have windows which area is from 14.3% to 18.3% of the wall area that is its windows must be artificial and it has always been as such.

However, further article 10.4 states "… Clarification of geometrical parameters of lighting aperture area should be carried out based on the calculation of CNL of natural illumination according to SCS V.2.5-28 "Natural and artificial lighting". As mentioned above, according to the new SCS V.2.5-28: 2018 [2], the increase in the area of translucent structures is not limited to the facades of modern residential buildings.

This can promote significant changes in the area of translucent structures on the facades in the architecture of modern residential buildings:

– from the minimum, when the area of translucent structures of a residential building is chosen with a permissible decrease in the value of CNL (no more than 10%, as provided by the new lighting norms);

– to the maximum – when the area of translucent structures of a residential building is chosen with a significant increase in the value of CNL (without restrictions from above, as provided by the new lighting norms).

Given that the changes adopted in the new SCS V.2.5-28:2018 will make possible that at the request of an architect the area of translucent structures on the facades of two identical residential buildings may differ significantly, several questions arise:

1. If the adopted changes of the new version of SCS V.2.5-28: 2018 "Natural and artificial lighting" [2], concerning non-limitation in the increase in the area of translucent structures on the facades of modern residential buildings to the requirements of DBN V.2.2.-15:2019 "Residential buildings" [3] article 10.4: "The ratio of the lighting aperture area in living rooms and kitchens to the floor area of these premises should be in the range from 1:5.5 to 1:8" and SCS V.2.6-31: 2016 "Thermal insulation of buildings" [4] article 4.13: "To reduce heat loss in winter and external heat gains in summer it is not recommended to design external translucent enclosure structures with a larger area than necessary, provided that the required level of natural light is in accordance with SCS V.2.5-28".

2. If it is possible for these two different options for facade glazing of residential buildings to choose the same minimal allowable value of heat transfer resistance of their translucent enclosure structures $R_{q\ min}$, as it is shown in Table 3 SCS V.2.6-31:2016 "Thermal insulation of buildings" [4]; for example, for Odesa – II temperature zone – $R_{q\ min} = 0.6\ m^2{\cdot}K/W$ or whether in this case, it is necessary to choose different solutions for them.

As the analysis of the reference documents and scientific publications on their discussion shows, these issues were not raised or considered. Therefore, it is important to consider them, as it is done by the authors in this article.

Purpose and objectives of the work. To analyze the question of how the approved changes in the new SCS V.2.5-28: 2018 [2] will affect the choice of architectural solutions of translucent elements of the facades of modern designed residential buildings and their energy efficiency.

Materials and methods of research. The research analyzed reference documents of Ukraine, the catalogues of translucent structures of various companies and scientific publications using the following materials:

Reference documents:

– SCS V.2.5-28:2006. Pryrodne i shtuchne osvitlennya. Zmina 2. K.: Minbud Ukrayiny, 2012 [1];
– SCS V.2.5-28:2018. Pryrodne i shtuchne osvitlennya. K.: Minrehion, 2018 [2];
– SCS V.2.2-15-19. Zhytlovi budynky. Osnovni polozhennya. K.: Minrehion, 2019 [3];
– SCS V.2.6-31:2016. Teplova izolyatsiya budivelʹ. K.: Minrehionbud, 2017 [4].

- *Catalogues of translucent structures of companies:*

– Unikal'naya innovatsionnaya fasadnaya sistema Qbiss Air [5];
– Profiled Glass with System Pilkington [6];
– Heat Mirror Glass – Nauka Teplovogo Zerkala [7];
– Vikna REHAU [8]; Vikna SHUKO v Ukrayini [9] etc;

- *Publications and forums:*

– Zhytlovyy kompleks «Bilyy parus» – poyednannya stylyu i komfortu – Vikna.ua [10];
– Zhytlovyy kompleks «Bilyy parus» – Odesʹkyy forum [11];
– Perlyny 24-25 vid Kadorr Group: INTERWINDOWS [12];
– Perlyny vid Kadorr Group – Vsi ZHB vid Kadorr Group [13];
– Svetoprozrachnyye fasady i osnovnyye sistemy fasadnogo ostekleniya [14] etc.

Results of research. The analysis of changes in only one indicator in the new lighting standards – the alteration in the allowable deviation of the calculated value of CNL from the normalized (Appendix M, p. 121, [2]), when its decrease is limited to 10% and the increase is not limited, allowed to establish that now when choosing the translucent elements of facades of modern buildings, the allowable restriction of the area of translucent designs concerns only its possible decrease, while the increase is not limited.

This confirms that the approved changes in the new lighting norms can lead to the situation when two residential buildings of the same purpose (e.g., residential) with the same indicators (the number of floors; the number of apartments and their size, etc.) at the request of the architect may differ significantly in the architectural solution of translucent structures of their facades and be differently perceived architecturally: one house may have a small lighting aperture area in the form of separate artificial windows on the facades (option 1), and another house may have a large lighting aperture area in the form of continuous glazing facades (option 2), which can be seen from the following examples:

– *option 1* – when the area of translucent structures of a residential building is minimal and chosen with a permissible decrease in the value of CNL (not more than 10%, as provided by the new lighting norms) and forms separate artificial windows on the facades of the residential building – examples of such facades are shown in Fig. 1 – reconstruction of old residential buildings in Odessa and Fig. 2 – new high-rise buildings in Frantsuz’ky Boulevard in Odessa;

– *option 2* – when the area of translucent structures of a residential building is the maximum and is chosen without limiting the value of CNL (as provided by the new lighting norms) and forms continuous glazing of external walls on the facades of a residential building - examples of such facades are shown in Fig. 3 – residential complex MANHATTAN CITY in Kyiv and in Fig. 4 – residential buildings Perlyny 24 and 25 from Kadorr Group in Odessa – projects of new high-rise residential buildings.

Fig. 1. Reconstruction of a residential building in Odessa – the corner of Polska Street and Devolanovsky Descent

Fig. 2. New residential buildings in Frantsuz′kiy Boulevard in Odessa

Fig. 3. Residential complex MANHATTAN CITY in Kyiv

Fig. 4. Residential buildings Perlyny 24 and 25 in Odessa

Hence, only this change in the new lighting norms can significantly affect the architectural solutions of the facades of the designed residential buildings: they can differ significantly in the area of glazing of their facades:

– *the facades of one type of buildings – (option 1)* – separate artificial windows on facades, Fig. 1 and 2 – windows are chosen with the restriction of reducing the area of translucent structures on the facades of residential buildings – they have a minimum glazing area in the range from 1:5.5 to 1:8 of the floor area, and the glazing area of these windows can be from 14.3% up to 18.3% of the area of the external walls of the house that is, they are artificial windows on the facades of a residential building; in this case, adopted changes to the new version of SCS V.2.5-28:2018 "Natural and artificial lighting" [2] meet the regulatory requirements of article 10.4 SCS V.2.2.-15:2019 "Residential buildings" [3] and article.4.13 SCS V.2.6-31:2016 "Thermal insulation of buildings" [4] – this will help reduce heat loss in winter and heat gains in summer;

– *the facades of another type of buildings – (option 2)* – continuous glazing of facades, Fig. 3 and 4 – windows are chosen without limiting the increase in the area of translucent structures on the facades of modern residential buildings; they have a maximum glazing area that can cover up to 100% of the area of the external walls that is, continuous glazing of external walls; in this case, the versions of SCS V.2.5-28:2018 "Natural and artificial lighting" [2] do not meet the requirements of article 10.4 of SCS V.2.2.-15:2019 "Residential buildings" [3] and article 4.13 of SCS V.2.6-31:2016 "Thermal insulation of buildings" [4] – this will increase heat loss in winter and heat gains in summer.

It should be noted that such changes in the architectural solutions of the facades of residential buildings can significantly influence their thermal performance and energy efficiency of their external enclosing structures, that is, affect the thermal insulation of buildings. The analysis of this issue is considered in this article and is given below. Thermal requirements for external enclosing structures of facades of residential and public buildings are presented in Table 3 SCS V.2.6-31: 2016 "Thermal insulation of buildings". K.: Minregionbud, 2017 [4], which scheme is presented below.

Table 3 – The minimum allowable value of heat transfer resistance of the enclosing structure of residential and public buildings $R_{q\ min}$ [4]

No	Type of enclosing structure	Value $R_{q\ min}$, $m^2 \cdot K/W$, for temperature zone	
		I	II
1	External walls	3.3	2.8
2	Combined coatings	6.0	5.5
3	Covering of heating attics	4.95	4.5
…	……………………………..	…	…
6	Translucent enclosing structures	0.75	0.6
7	Exterior doors	0.6	0.5

Table 3 shows that for choosing $R_{q\ min}$, it is necessary to set the following indicators [3]: the temperature zone of the city of construction and the type of enclosing structures:

The temperature zone of the city of development is chosen according to the Map-scheme of temperature zones of Ukraine [3], which is presented below in Fig. 5 – for example, Odessa is in the second temperature zone.

Fig. 5. Schematic map of temperature zones in Ukraine
(SCS V.2.6-31: 2016 "Thermal insulation of the building," Appendix B [4])

Types of enclosing structures, which are defined in Table 3 [4], can be represented in different building materials and are divided as follows:

No1 – External walls – material: brick, aerated concrete, continuous glazing, etc.;

No 2 – Combined coatings – material: reinforced concrete, glass atrium, etc.;

…………………………………..

No 6 – Translucent enclosing structures – material: artificial glass elements of the facade – windows, doors, stained glass, etc.

This article analyzes two different options for the external walls glazing of the facades of residential buildings, which are located in Odessa (temperature zone II of Ukraine) and for which Rq_{min} is determined according to Table 3 [4]:

– *Option 1 – Separate artificial windows on the external walls of the facades* of a residential building (Fig. 1 and Fig. 2) – this construction can be attributed to No 6 of Table 3 [4] – Translucent fencing structures – artificial glass elements of the facade of the house (windows) – heat-protective properties must meet the following requirements:

$$R_{\sum\ given\ option\ 1} \geq R_{q\ min} = 0.6\ m^2 \cdot K/W.$$

That is, translucent constructions of facades of houses with separate artificial windows require low levels of heat-protective properties, which should provide heat transfer resistance $R_{q\ min} \geq 0.6\ m^2 \cdot K/W$ and it is possible to use ordinary silicate glass for them – this is the cheapest and most acceptable option for the construction of social group facilities (for example, preschool institutions, schools, municipal hospitals, social housing, etc.).

– Option 2 – Continuous glazing of the external walls of the facades of a residential building (Fig. 3 and 4) – this design can be attributed to No 1 of Table 3 [4] – External walls – a continuous glass case of the facade of the house, for which the thermal properties must meet different requirements:

$$R_{\sum\ given\ option\ 2} \geq R_{q\ min} = 2.8\ m^2 \cdot K/W.$$

Thus, residential buildings the outer walls of which are facades with a continuous glass case must have much higher thermal insulation properties – as for external walls $R_{q\ min} \geq 2.8\ m^2 \cdot K/W$ – that is, the minimum allowable value of their heat transfer resistance should be 4.66 times higher than for artificial windows.

Translucent constructions of facades of the buildings with continuous glazing of external walls (option 2) require $R_{q\ min} \geq 2.8\ m^2 \cdot K/W$, that is, it is necessary to provide high levels of heat-protective properties and the use of ordinary silicate glass is no longer suitable for this because such high heat-protection properties can be provided only by modern glass, such as Qbiss Air, Pilkington, Heat Mirror Glass and multi-chamber double-glazed windows. All these modern translucent constructions provide high thermal insulation in winter and excellent protection from the sun and overheating in summer, which saves energy during the year for both heating and cooling and creates increased comfort. However, such modern translucent constructions of facades with a continuous glass cover are much more expensive than usual artificial windows with silicate glass, therefore they are mainly used for the building of elite houses - both residential and public.

Conclusion and prospects for further research. The results of research conducted in this article indicate that approved in the new lighting standard SCS V.2.5-28:2018 "Natural and artificial lighting" [2] alteration of only one indicator – the permissible deviation of the calculated value of CNL from the normalized [2], when its reduction is limited to 10%, and the increase is not limited – leads to the fact that two residential buildings with the same performance at the request of the architect can differ significantly not only in architectural solutions of their translucent facades but also in their thermal properties and they do not meet energy efficiency requirements of the current regulations:

1. SCS V.2.2.-15:2019 "Residential buildings" [3] – article 10.4: "The ratio of the lighting aperture area of living rooms and kitchens to the area of their floor should be in the range from 1:5.5 to 1:8".

2. SCS V.2.6-31:2016 "Thermal insulation of buildings" [4] – article 4.13: "To reduce heat loss in winter and heat gains in summer it is not recommended to design external translucent enclosing structures with an area larger than necessary provided that the required level natural light is in accordance with SCS V.2.5-28".

It should be noted that there is the question whether it is possible for two different options for glazing the facades of residential buildings (option 1 – artificial windows and option 2 – solid glass facade) to choose the same minimum allowable value of heat transfer resistance of their translucent enclosing structures $R_{q\ min}$, as it now remains in Table 3 of the current SCS V.2.6-31:2016 "Thermal insulation of buildings" [4]: for example, for the city of Odessa – temperature zone II – according to this table we have only $R_{q\ min} = 0.6\ m^2 \cdot K/W$, which meets the thermal protection requirements of artificial windows and is suitable for option 1, but does not meet the thermal protection requirements of the solid glass case of the facade and is not suitable for option 2, for which another glazing solution should be chosen which thermal protection properties should have $R_{q\ min} = 2.8$ that is, to be higher than for artificial windows 4.66 times – *however, it is not evident from Table 3.*

Therefore, in the perspective, studies should be provided for the adjustment of Table 3, the title and structure of which may be different, for example:

Table 3 (adjusted) – The minimum allowable value of heat transfer resistance of the enclosing structure of residential and public buildings

No	Type of enclosing structure (can be of different building materials)	Value $R_{q\ min,}$ for temperature zone	
		I	II
1	External walls – *material*: brick, aerated concrete, continuous glazing, etc.	3.3	2.8
2	Combined coatings – *material*: reinforced concrete, glass atrium, etc.	6.0	5.5
…	…………………………………………………………….	…	…
6	Artificial glass elements of the facade: windows, doors, stained glass, etc.	0.6	0.5

Compliance with this regulatory requirement will help ensure a comfortable microclimate of residential buildings, save energy for heating and cooling of their premises during winter and summer operation, and all these will be provided for less money.

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ЗМІНИ СВІТЛОТЕХНІЧНИХ НОРМ ТА ЇХ ВПЛИВ НА АРХІТЕКТУРУ І ЕНЕРГОЕФЕКТИВНІСТЬ СУЧАСНИХ ЖИТЛОВИХ БУДІВЕЛЬ

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Анотація. Державні нормативні документи з проектування освітлення житлових будівель за останні роки зазнали істотних змін, що в свою чергу суттєво впливатиме на архітектуру і енергоефективність сучасних будівель цього типу. Це можна спостерігати з наведеного в даній статті аналізу авторів щодо зміни лише в одному нормативному документі – ДБН В.2.5-28: "Природне і штучне освітлення" і лише одного світлотехнічного показника: допустиме відхилення розрахункового значення КПО від нормованого при виборі світлопрозорих конструкцій будинків. В даній статті представлено аналіз цього нормативного документу в двох редакціях – в старій від 2012р. і в новій від 2018р. За результатами проведеного аналізу авторами даної статті встановлено, що за бажанням архітектора площа світлопрозорих конструкцій на фасадах двох однакових сучасних житлових будинків може суттєво відрізнятись: від мінімальної із штучними вікнами на фасадах – де скління займає від 14,3% до 18,3% площі фасадів; до максимальної із суцільним склінням фасадів – де скління займає до 100% площі фасадів житлового будинку. Ці два варіанти скління фасадів не тільки архітектурно сприймаються по різному, але вони повинні ще мати різну енергоефективність, щоб забезпечувати різні мінімально допустимі значення опору теплопередачі: для штучних (окремих) вікон на фасаді це – $R_{\sum} \geq R_{q\ min}$= 0,6 $м^2 \cdot К/Вт$ і для їх скління підходить звичайне силікатне скло, але для суцільного скління фасаду це вже повинно бути $R_{\sum} \geq R_{q\ min}$ = 2,8 $м^2 \cdot К/Вт$, тобто вони повинні мати такі ж теплозахисні властивості як і зовнішні стіни і їх мінімально допустиме значення опору теплопередачі повинно бути в 4,66 рази більше ніж для штучних (окремих) вікон. Для цього варіанту вже не підходить звичайне силікатне скло, а потрібно використовувати сучасні склопрозорі конструкції з високими теплозахисними властивостями, наприклад Qbiss_Air, Pilkington, Heat Mirror Glass та інші. Вони забезпечують чудовий захист від переохолодження взимку і від перегріву влітку, а також мають хороші сонцезахисні властивості. Їх використання в сучасних будинках сприяє протягом року економії енергії на обігрів та на охолодження приміщень і створює підвищений комфорт, але такі світлопрозорі конструкції значно дорожчі і краще підходять для елітного домобудівництва, ніж для соціального.

Ключові слова: світлотехнічні норми, енергоефективність будівель, природне освітлення, світлопрозорі конструкції будівель.

ИЗМЕНЕНИЯ СВЕТОТЕХНИЧЕСКИХ НОРМ И ИХ ВЛИЯНИЕ НА АРХИТЕКТУРУ И ЭНЕРГОЭФФЕКТИВНОСТЬ СОВРЕМЕННЫХ ЖИЛЫХ ЗДАНИЙ

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Аннотация. Государственные нормативные документы по проектированию освещения жилых зданий за последние годы претерпели существенные изменения, что в свою очередь существенно будет влиять на архитектуру и энергоэффективность современных зданий этого типа. Это можно наблюдать из приведенного в данной статье анализа авторов по изменению только в одном нормативном документе – ДБН В.2.5-28: «Естественное и искусственное освещение» и только одного светотехнического показателя: допустимое отклонение расчетного значения КЕО от нормируемого при выборе светопрозрачных конструкций зданий. В данной статье представлен анализ этого нормативного документа в двух редакциях – в старой от 2012г. и в новой от 2018р. По результатам проведенного анализа авторами данной статьи установлено, что по желанию архитектора площадь светопрозрачных конструкций на фасадах двух одинаковых современных жилых зданий может существенно отличаться: от минимальной со штучными (отдельными) окнами на фасадах – где остекление занимает от 14,3% до 18,3% площади фасадов; до максимальной со сплошным остеклением фасадов – где остекление занимает до 100% площади фасадов жилого дома. Эти два варианта остекления фасадов не только архитектурно воспринимаются по-разному, но они должны еще иметь разную энергоэффективность, чтобы обеспечивать различные минимально допустимые значения сопротивления теплопередаче: для штучных (отдельных) окон на фасаде это $R_{\Sigma} \geq R_{q\ min} = 0{,}6$ м^2·К/Вт и для их остекления подходят обычные силикатные стекла, а для сплошного остекления фасада это уже должно быть $R_{\Sigma} \geq R_{q\ min} = 2{,}8$ м^2·К/Вт, то есть они должны иметь такие же теплозащитные свойства как и внешние стены, а их минимально допустимое значение сопротивления теплопередаче должно быть в 4,66 раза больше чем для штучных (отдельных) окон. Для этого варианта уже не подходит обычное силикатное стекло и нужно использовать современные светопрозрачные конструкции с высокими теплозащитными свойствами, например, Qbiss Air, Pilkington, Heat Mirror Glass и другие. Они обеспечивают превосходную защиту от переохлаждения зимой и от перегрева летом, а также имеют хорошие солнцезащитные свойства. Их использование в современных зданиях способствует в течение года экономии энергии на обогрев и на охлаждение помещений и создает повышенный комфорт, но такие светопрозрачные конструкции значительно дороже и лучше подходят для элитного домостроения, чем для социального.

Ключевые слова: светотехнические нормы, энергоэффективность зданий, естественное освещение, светопрозрачные конструкции зданий.

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