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THE SIMPLE WAY TO UPGRADE THE DAYLIGHT STANDARD FOR TROPICAL VIETNAM

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ABSTRACT

Climate change and the environmental pollution during the building operation in the last years cause of the reconsideration of exits standards/guidelines in buildings. Recent studies show the nonconformity of these guiding documents, which do not fully consider the climate of the regions when building the recommendations. As a result of this lack, the building operation does not reach the energy efficiency together with the thermal and visual comfort.

This paper proposes a simple method to recalibrate the daylight standard with the Daylight Factor criteria for Vietnam based on analysis of the daylight climate potential of the location and the requirement of daylight usage on the relative time and space. This bio-climatic approach refers to the design of buildings in the consideration of local climate aimed at providing thermal and visual comfort with the rational use of solar energy and other environmental sources. The result of this study helps to improve the current standardized methods of day lighting evaluation in Vietnam with a modern approach. In order to conduct a meaningful comparison between different climate regions, an analysis of two input climate data for tropical Hanoi (Vietnam) and temperate Moscow (Russia) was considered.

Keywords: energy efficiency, visual comfort, daylight assessment, daylight standardization, daylight climate

1. INTRODUTION[1]

Daylight assessment by the state of the CIE overcast sky has disadvantages, especially for tropical regions where the overcast sky is not typical. Using the overcast skies for the daylight standardization suggesting a high Daylight Factor (DF) recommendation and raises the problem of glazing facades of office buildings, which causes serious problems with glare, overheating inside and inefficacy of energy consumption of buildings. This sky condition was used in the "Natural Lighting in Civil Works – Design standard – TCXD29:1991" of Vietnam. The Average Daylight Factor (ADF) in this document was taken from the standard "Posobie K Snip II-4–79 Natural and Artificial Lighting", which proposed for the temperate region of Russia. In addition, the daylight performance in the room changes all the time in a space, whereas the average Daylight Factor is a stable value and does not inform about the distribution of the illuminance in time and space [1–4]. In the recent studies, the indicator for daylight standardization should be based on a static assessment with a representative of the Daylight Factor, taking into account the relative time of daylight usage requirement and the relative area of daylight space requirement. This approach is widely adopted in the research association. By this way, the

[1] The edition form Snip II-4-79 and Snip 23-05-95 - Natural and artificial lighting

Table 1. Recommendation of the Average Daylight Factors for Vietnam (TCXD 29:1991) [5] and Russia (SP 52.13330.2016) [6]

Illuminance on the working surface (lx)	Vietnam		Russian	
	ADF (%)	DF_{min} (%)	ADF (%)	DF_{min} (%)
500	5.0	2.5	4.0	1.5
400	–	–	3.5	1.2
300	3.0	1.5	3.0	1.0
200	2.0	1.0	2.5	0.7
150	1.5	0.8	2.0	0.5
100	1.0	0.5	2.0	0.5

Note to Table 1: ADF – Average Daylight Factor, DF_{min} – Minimum Daylight Factor at an unfavourable point, which in 1m from the most distant wall.

daylight standards in buildings need to be updated for the tropical climate of Vietnam.

According to data of standards [5, 6] the recommendations of the average Daylight Factors for Vietnam and Russia are given in Table 1.

In the research [1] was shown that there are two ways of daylight standardization: the standardization of daylight in accordance with simple static criteria Daylight Factor with the overcast sky condition. The second way is based on dynamic criteria Daylight Autonomy, which related to the absolute value of daylight illuminance (DI). This approach was using on LEED and ASHREA recommendation for various clear sky options. Corresponds to The Buildings Research Establishment Environmental Assessment Method (BREEAM) guidelines describe two ways in which compliance can be demonstrated in order to attain the single credit available for daylighting. The criteria available are based on either "Daylight Factor" or "Daylight Illuminance":

- Daylight Factor (DF) – achieve a minimum average Daylight Factor across 80 % of the "relevant area" at working plane height;
- Daylight illuminance (DI) – achieve an average of at least 200 lx for 2650 hours per year or more and also at least 60 lx for 2650 hours per year of more at the "worst lit" point.

The Average Daylight Factor (ADF) depends on latitude for the space under evaluation, ranging from 1.5 % for latitudes less than 40° N to 2.2 % for latitudes greater than 60° N. Another proposal of the median target Daylight Factor value from 1.7 % to 2.6 % were define for European cities covering a wide range in latitude from 35° N to 64° N [3, 4]. However, the proposal for the tropical climate in lower latitude, where the daylight climate characterize with high level of diffuse horizontal illuminance was absent.

1.1. Static criteria – the Daylight Factor

This value was conceived as a means of rating daylighting performance independently of the actually occurring, instantaneous sky conditions. Whereas, it was defined as the ratio of the internal horizontal illuminance (E_{in}) to the unobstructed (external) horizontal illuminance (E_{out}), usually expressed as a percentage, determined by equation (1):

$$DF=\frac{E_{in}}{E_{out}}100\%. \quad (1)$$

Normalized DF is based on the works of Glagoleva T.A. (1961), which proposed to determine the Daylight Factor from the condition of equality of the logarithms of the amount of natural and artificial lighting in the room for the year. In modern norms, this relationship is determined by the simple equality of the number of artificial and natural lighting per year [7]. Hence, the algorithm may be described in formulas from (2) to (4):

$$DF=\frac{A_{in}^{annual}}{A_{out}^{annual}}100\%, \quad (2)$$

$$A_{in}^{annual}=12\cdot E_{in}^{norm}\cdot T_w\cdot N_W, \quad (3)$$

$$A_{out}^{annual}=\sum_{i=1}^{i=12}N_w\int_{T_1}^{T_2}E_{out}dt, \quad (4)$$

where A_{in}^{annual} is the annual amount of artificial illumination of the interior during the year; A_{out}^{annual} is the annual amount of natural horizontal illumination from the outside is obtained by integrating the functions by changing the external illumination over time in each month and summing the integrals with multiplying this amount by the number of working days in the month; E_{in}^{norm} is the artificial lighting according to the standards required by the types of work or the target illuminance (lx); E_{out} is the average monthly value of diffuse horizontal illumination by working hours (lx); N_w is the number of working days per month (day); T_w is the number of working hours per working day (hours).

On the other hand, the average Daylight Factor (ADF) equation, which was proposed by Lynes (1979) [8] was revised by Crisp and Littlefair (1984) [9]. The ADF calculation is expressed by equation (5):

$$\overline{DF}=\frac{T*W*\theta*M}{A*(1-R^2)}, \quad (5)$$

where $\overline{DF}$ is the average Daylight Factor; T is the coefficient transmittance of the window(s); W is the net area of window(s); θ is the angle in degrees subtended in vertical plane by sky visible from the centre of a window; M is the maintenance factor; A is the total area of bounding surfaces of the interior; R is the area-weighted mean reflectance of interior bounding surfaces.

1.2. The Dynamic Daylight Assessment by Using Values sDA, ASE and UDI

The dynamic daylighting assessment was created to develop a new suite of metrics on the predictive performance of historical metric such as Daylight Factor [2, 10–13]. The values spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) as describe in previous researches [14–16] together create a clear picture of daylight efficiency and more importantly they can help architects make the right design decisions. The sDA describes how much light is available during standard operating hours. In particular, it describes the percentage of floor space that receives at least 300 lx (for offices) at least for 50 % of working hours per year. The sDA value between 55 % and 74 % indicates the space in which natural lighting is “nominally taken”.

In addition to meeting the daylight sufficiency performance criteria above, successfully daylight spaces must also ensure the visual comfort of the occupants. One metric of the probability of visual discomfort is the number of hours that direct sunlight can potentially enter a space. This metric is called Annual Sun Exposure (ASE). In particular, ASE measures the percentage of floor space that receives at least 1000 lx for at least 250 busy hours per year. In the supporting research, daylight spaces were predicted to have no more than 10 % were judged to have satisfactory visual comfort. These dynamic daylight assessment metrics are present proposed on the activities of certification of building environment or building sustainability, e.g. LEED, BREEAM, DNGB credits system.

The Useful Daylight Illuminance scheme (UDI) was first published in 2005 [17, 18] with the lower and upper bounds of 100 lx and 2000 lx. A few years later, the upper value was revised upwards to 3000 lx according to data from previous researches [18, 19].

1.3 Research Objective

Daylight in a space is permanently changing during a day in intensity and spatial distribution in depend on position of the sun on the sky firmament. Therefore, the values indicate changes of daylight in time and space have been developed and are described in the Approved Method: IES Spatial Daylight Autonomy (sDA) [14], which allow the daylight space to be evaluated for a one-year period. As a result of calculations, designers, architects, engineers can quickly correct the parameter of the apertures of existing projects to meet the standards values. However, according to this approach, the proposed method for determining the WFR at the design stage is absent since this ratio is related to the DF in accordance with the ratio of target illuminance to the external diffuse horizontal illuminance. Therefore, a design should complete a target Daylight Factor (DF_T) at the height of the work plane across half of the relevant floor area for half of the daylight hours per year, also achieve a target minimum Daylight Factor (DF_{TM}) at the height of the work plane across all of the relevant floor area for half of the daylight hours per year. The relevant floor area is the entire regularly occupied floor space inside the perimeter zone of (0.5 ÷ 1) m [4].

The main objective of present investigation is to study the target Daylight Factor and it is determined when considering the following issues:

- The connectivity with the daylight climate based on cumulative diffuse horizontal illumination;
- The target illuminance value;

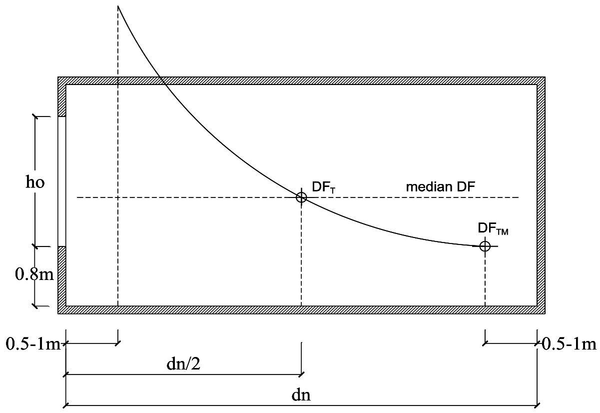


Fig. 1. Section of the room with an illustration of the DF_T and the DF_{TM} requirement

• The relative area of daylight space requirement;

• The relative time of usage daylight requirement in space, it depends on the fixed period of time.

2. METHODS

Proposed method is established on the standardization Daylight Factor according to the tasks above by using the curve of means annual diffuse horizontal illuminance. Corresponds to formula (1), the target Daylight Factor is determined by the ratio of the target illuminance to the target external diffuse illuminance (the critical Illuminance) and shows by equation (6).

$$DF_T = \frac{E_T}{E_{cr}}.100\%, \quad (6)$$

where E_T is the target indoor illuminance (lx); DF_T is the target Daylight factor (%); E_{cr} is the critical Illuminance (lx).

2.1 The Daylight Climate Connectivity

The studies of daylight climate in the daylight assessment were described in published researches [3, 18, 19]. From the formulas (1) and (6), it is seen that the external horizontal illuminance in the calculation depended on daylight climate of each region, characteristic of which is reflected in the cumulative diffuse illuminance curve. The diffuse illuminance data are available at numerous actinometric stations. If the measured diffuse horizontal illuminance data are not available, the diffuse luminous efficacy K_D, is typically applied to obtain the diffuse horizontal illuminance from the more widely available diffuse irradiance data form studies [20, 21]. To simplify the calculations, it is supposed to use the curve of means annual diffuse horizontal illuminance.

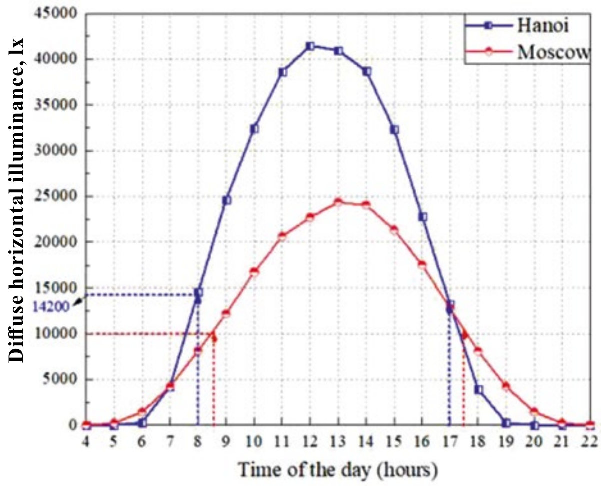


Fig. 2 The curves of average diffuse horizontal illuminance for Hanoi and Moscow

2.2. The Values of Target Illuminance E_T

Characteristics of visual work allow us to assign a category to visual work, and defined it by the target illuminance E_T within the range 100 lx to 500 lx. Particularly, a target illuminance of 300 lx is related to the concept of "well daylight space", and this value is described as suitable illuminance for "prolonged office work" [14].

2.3. The Relative Area of Daylight Space Requirement

The distribution of a daylight space is indicated by the median target Daylight Factor (DF_T), which ensures that at least 50 % of relative area has reached the target illuminance of 300 lx and all of the relevant floor area has reached the target minimum illuminance of 100 lx at work plane height across [3, 4, 19]. This mean the ratio of $\frac{DF_{TM}}{DF_T}$ at least should be 1/3 and shown in Fig 1.

2.4. Percentages of Daylight Usage Time Depend on the Fixed Period of the Day

To obtain the percentages of daylight usage time, a fixed period of the day depends on the occupied period need to be chosen. Several assumptions respecting regional life-style, activity pattern or target skylight requirements can be taken into account. For

Table 2. Recommendation of DF_T and E_{cr} for the Working Time Period

Location	E_T (lx)	Relative time of daylight using (%)					
		50		80		100	
		DF_T	E_{cr}	DF_T	E_{cr}	DF_T	E_{cr}
Hanoi	500	1.5	33300	2.25	22200	3.5	14200
	400	1.2	33300	1.8	22200	2.8	14200
	300	0.9	33300	1.35	22200	2.1	14200
	200	0.6	33300	0.9	22200	1.4	14200
	100	≤ 0.5	33300	≤ 0.5	22200	0.7	14200
Moscow	500	2.5	20000	3.4	14650	5	10000
	400	2.0	20000	2.7	14650	4	10000
	300	1.5	20000	2.0	14650	3	10000
	200	1.0	20000	1.4	14650	2	10000
	100	0.5	20000	0.7	14650	1	10000

Note to the Table 2: E_T is the target illuminance (lx); DF_T is the median target Daylight Factor (%); E_{cr} is the criterion Illuminance (lx).

instance, some most probable daily activity hours e.g. 7h00 ÷ 20h00, 8h00 ÷ 17h00, 8h00 ÷ 19h00 or 9h00 ÷ 16h00 [1]. By propose of IES, the temporal range used in the calculation of Daylight Autonomy is the working hours, usually from 8h00 to 18h00 [14]. But finally, for all CEN capitals the recommendations of daily periods from sunrise to sunset were applied [1, 3, 4].

In order to make a meaningful comparison between the different considered period of working time and all daylight hours, it was decided to compare the target daylight factor, which was converted to satisfy the daylight space for each selected period of time. Two cases study of the comparison for tropical Hanoi, Vietnam and temperate Moscow were conducted.

3. RESULTS

In order to test, we used the climate hourly typical data ASHRAE IWEC2 file from 2005 to the end of 2017 for Hanoi [22] and the freely available climate files were downloaded from the EnergyPlus website for Moscow city.

3.1. Results of Cases Study

Based on the weather data of the regions, the curves of average diffuse horizontal illuminances for Hanoi (21.03^0 N) and Moscow (55.75^0 N) were built and presented in Fig. 2 [20–23].

In the Fig. 2 is shown that, the working period was proposed for Vietnam from 8h00 to 17h00, for Moscow from 8h30 to 17h30, these periods ensure

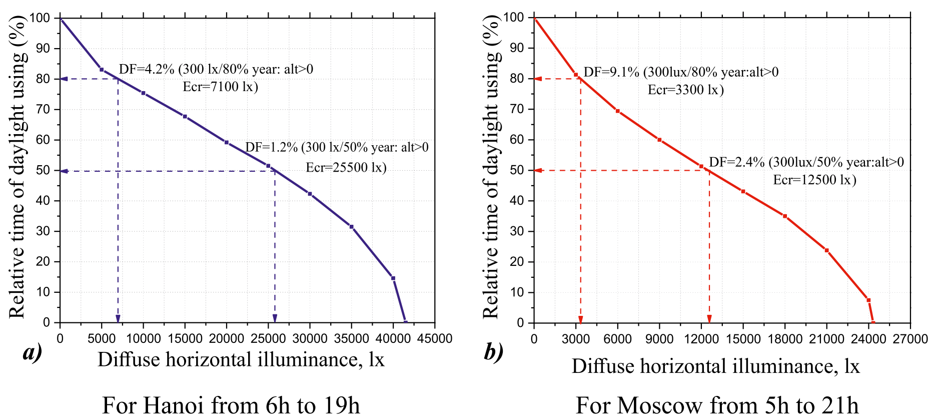
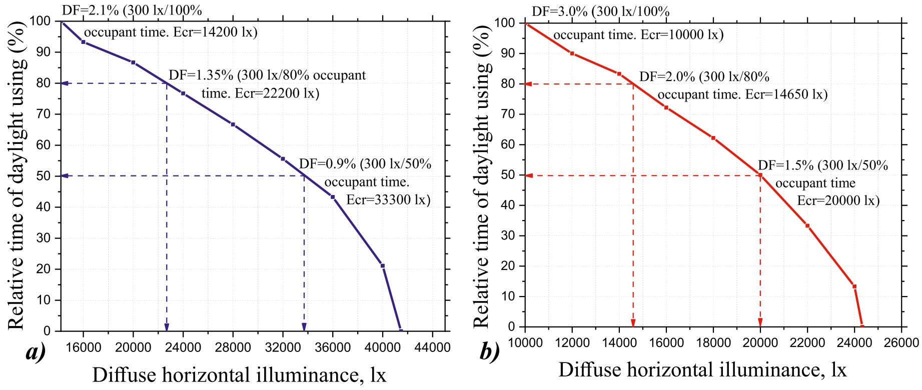


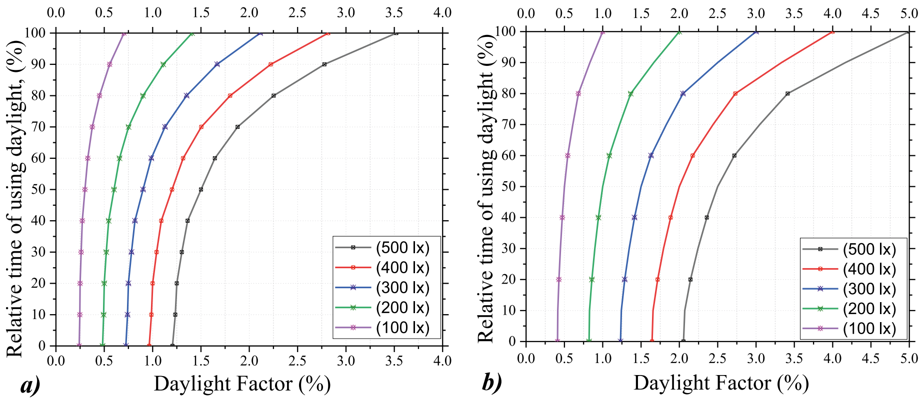
Fig. 3. Cumulative diffuse illuminance curve for period of daylight hours



for Hanoi from 8h to 17h

for Moscow from 8h30 to 17h30

Fig. 4. Cumulative diffuse illuminance curve for period of working hours



For Hanoi

For Moscow

Fig. 5. Recommendation of target Daylight Factor in relate with percentages of daylight usage time for period working hours

the "balance" of the diffuse horizontal illuminance distribution over time. To inform the relationship of DF_T to relative time of daylight using from the fixed period with difference target Illuminance E_T, the cumulative diffuse illuminance curves were obtained in Fig. 3 for the fixed period is all daylight hours and in Fig. 4 for the fixed period is working hours.

Table 3. Recommendation of DF_T and E_{cr} for All Daytime Period from Sunrise to Sunset

Location	E_T (lx)	Relative time of daylight using (%)			
		50		80	
		DF_T	E_{cr}	DF_T	E_{cr}
Hanoi	500	2.0	25500	7.0	7100
	400	1.6	25500	5.6	7100
	300	1.2	25500	4.2	7100
	200	0.8	25500	2.8	7100
	100	0.4	25500	1.4	7100
Moscow	500	4.0	12500	15.0	3300
	400	3.2	12500	12.0	3300
	300	2.4	12500	9.1	3300
	200	1.6	12500	6.1	3300
	100	0.8	12500	3.1	3300

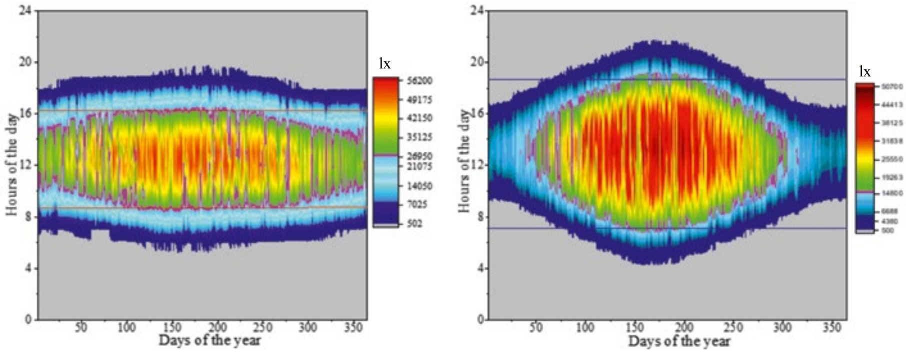
It is seen that to achieve the target illuminance 300 lx at least half of the daylight hours in the year, the target Daylight factors were defined 1.2 % and 2.4 % with the median values of diffuse horizontal illuminance are 25500 lx and 12500 lx respectively for Hanoi and Moscow (Fig. 3).

On the other hand, in the comparative analysis with the period of working hours (shows in Fig. 4). In general, the DF_T values were considered at the various percentages of daylight usage time to meet the different target illumination and were illustrated in Fig. 5.

Results of this work shown that the target DF are 1.2 % and 2.4 % for Hanoi and Moscow cover about 80 % the working hours of Hanoi from 8h00 to 17h00 and approximately 90 % working hours from 8h30 to 9h30 of Moscow. Form data in Tables 2 and 3 were shown the recommendation of DF_T depend on percentages of daylight usage time with different fixed period of time.

3.1. Discussion

A recommendation of the target Daylight Factor for 33 capital cities of EU and CEN by Mardaljevic



a) ***b)***

Fig. 6a Distribution of selected diffuse data for Hanoi
Fig. 6b Distribution of selected diffuse data for Moscow

Table 4. Recommendation for DF_T and E_{cr} for All Daylight Hours Period Using the Median Value for the Retained Diffuse Horizontal Illuminance Data

Location	E_T (lx)	DF_T (%)	E_{cr} (lx)
Hanoi	300	1.1	26950
Moscow	300	2.1	14800

et. al. in the published studies [3, 4, 19] was considered when comparing with the proposed results. Accordingly, the authors used the diffuse horizontal illuminance values from the annual time-series with 8760 values and then extracting exactly half of the hours of the year, i.e. the 4380 highest values for the condition sun altitude ≥ 0^0 from sunrise to sunset. The median value for the retained diffuse horizontal illuminance data is then easily determined. By this method, the results were obtained for Hanoi and Moscow (Table 4): at the median diffuse horizontal illumination E_{cr} = 26950 lx and 14800 lx, the target values of Daylight Factor are 1.1 % and 2.1 % for Hanoi and Moscow, respectively. The result also shows a good consistent between the two approaches.

In Figs. 6a and 6b, distributions of diffuse horizontal illuminance from the median value for each location are shown. Graphs analysis using allows us to define flexibly the recommendation for DF_T to ensure requirements of a daylight space.

A measurement of daylight factor in working space in Hanoi: an experimental study with an office room at the 20th floor of the EVN tower, Hanoi was investigated on 6th July 2018. The room with typical reflectance values, large glass-opening of "single layer of window glass in steel single blind covers" with Window to Floor Ratio (WFR) of 30 %. Parameters of the depth of the room dn –8.7 m; the height from the level of the working surface to the height of the window head h_0–2.7 m (Fig. 8). We will consider the theoretical calculated median and

Table 5. Example of the Coefficient k_1 Values (SP 367.1325800.2017)

Types of filling of the light openings	Coefficient k_1
Single layer of window glass in steel single blind covers	1.26
Single layer of window glass, in the opening bindings	1.05
Single layer of window glass in wooden single opening binders	1.05

minimum Daylight Factor values and the measured values.

The theoretical calculated median and minimum Daylight Factor values: According to the experiments, the relationship between the WFR values and the minimum DF (DF_{min}) was determined by using the graph in Fig. 7 (SP 367.1325800.2017) [6], which was developed in relation to the most common in the design practice dimensional schemes of the rooms and typical solution of translucent structures – "wooden paired opening covers". It is noted that the minimum Daylight Factor (DF_{min}) is the

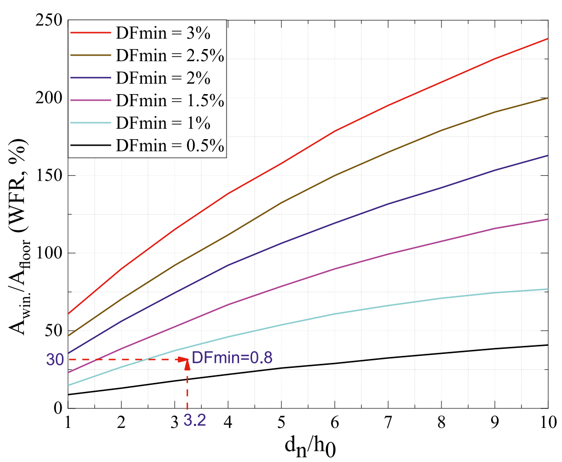
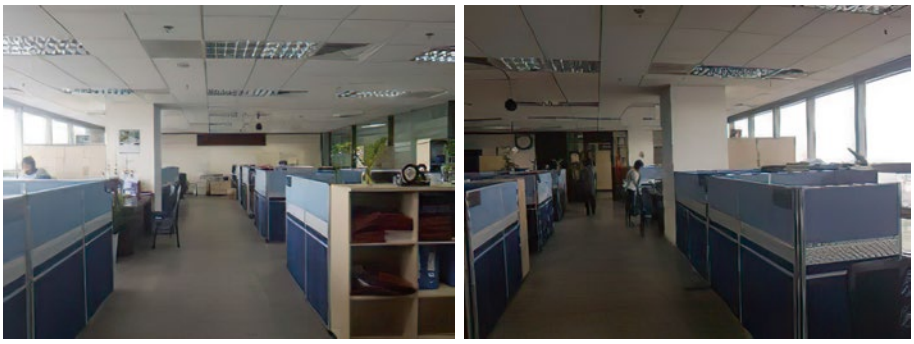
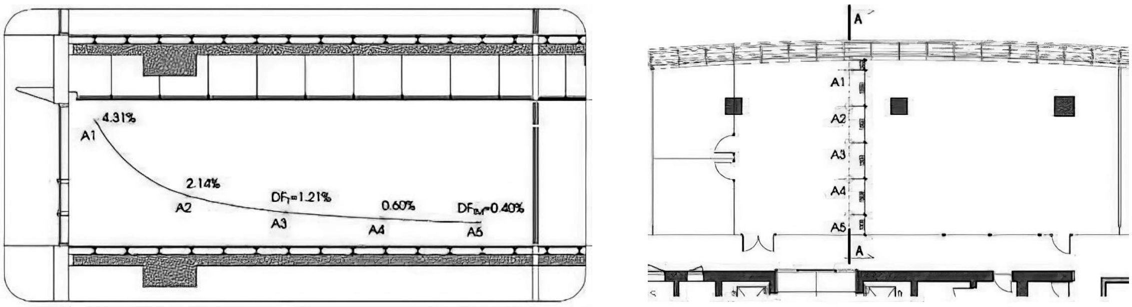


Fig. 7. Graph of WFR definition with different ratios d_n/h_0



a) *b)*

Fig. 8. Daylight in the office space of the EVN tower in Hanoi (Vietnam) (a) and interior of working space (b)



a) *b)*

Fig. 9. Daylight in the office space of the EVN tower in Hanoi (Vietnam), section A-A (a) and plan of the room (b)

Daylight Factor at an unfavourable point on the working plane, which in 1 m from the most distant wall.

If the design adopted other types of filling openings, the values of WFR found in Fig. 7 should be divided and the DF_{min} should be multiplied by the factor k_1 given in Table 5 [6].

With the parameters of the experimental building, i.e. the ratio d_n/h_0 = 3.2 and the WFR = 30 %, the measured ratio DF_{min}/DF_{med} =1/3, using the graph (Fig. 7) and the value of k_1 (Table 5), the results were obtained with DF_{min} = 0.8*1.26 = 1 % respectively median value DF_{MED} = 3 %. The large opening also causes problems of overheating of the room in the summer period and visual discomfort. In this case, to protect against glare is recommended to use the sun shading device or sunscreen.

The measured median and minimum Daylight Factor values: The illustration of the interior of the working space.

The results of experiment in Figs. 8, 9 and Table 6 show the median and minimum Daylight Factor values of EVN tower in Hanoi. It is seen the common problems of designing a daylight space: an office room with large glass-opening WFR of 30 %, but due to irrational placement of interiors with the partitions, the Daylight Factor values at the middle point and at the unfavourable point of the room significantly decrease respectively to 1.21 % and 0.4 %. The measured median Daylight Factor is in good agreement with the recommended target Daylight Factor in the Table 4. The analysis revealed the irrational of the designed WFR from the experiment. Therefore, in order to ensure daylight in a space, it is necessary to take into account the recommended size of the opening and rationality of interior design.

4. CONCLUSIONS AND FUTURE WORKS

According to the calculation results, the following conclusions are drawn:

Standardization daylighting with the Daylight factor based on selection criteria: characterize of the daylight climate of the region; requirement of the target illuminance; daylight requirement by time and space. In which connection, daylight space achieve at least half of the relevant floor area for half of the daylight hours per year as requirement of the international standards. Therefore, the target DF has been recalibrated as the median value in a space. This is the bioclimatic design basic of the project.

Daylight in space always is a compromise. With the proposed method, it is the flexible and the reasonable approach to upgrade Daylight standard in consideration of the "balance" of time using day-

Table 6. Measurement of the Median and Minimum Daylight Factor Values (EVN Tower, Hanoi)

Time	D_n/h_0	$E_{out,\ lx}$	Median values		Minimum values		DF_{med}/DF_{min}
			$E_{med,\ lx}$	DF_{med}	$E_{min,\ lx}$	DF_{min}	
8h30–9h00	3.2	43250	522	1.21	172	0.40	3.0

Note to the table 6: d_n is the depth of the room (m); h_0 is the height from the level of the working surface to the height of the window head (m); E_{med} is the median value of illuminance (lx); DF_{med} is the median value of Daylight Factor (%); E_{min} is the minimum value of illuminance (lx); DF_{min} is the minimum value of Daylight Factor (%).

light agreeably to the distribution of the outside illuminance in each region.

Compared with the current standard, the proposed DF_T values are presented smaller, corresponds to the tropical climate characteristics, reduces over glazing facades, and as a result reduces the heat transfer to the room.

A case study of an office building in Hanoi revealed the problems of over-glazing of façade design and the inefficient daylight using in the working space. Therefore, the connection of the recommended target Daylight Factor and the rational opening ratio at the design stage should be developed in subsequent studies.

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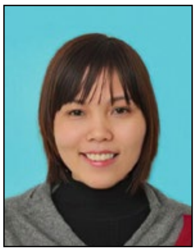

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