COMPUTATIONAL RESEARCH PROGRESS IN APPLIED SCIENCE & ENGINEERING (CRPASE)

CRPASE: TRANSACTIONS OF CIVIL AND ENVIRONMENTAL ENGINEERING

Journal homepage: http://www.crpase.com

CRPASE: Transactions of Civil and Environmental Engineering 9 (2) Article ID: 2846, 1–7, June 2023 ISSN 2423-4591

Research Article

Investigation of Illuminance Levels of Classrooms on Different Storey with or without Artificial Lighting

Tuğba İnan Günaydın*

Niğde Ömer Halisdemir University, Department of Architecture, 51240 Niğde, Turkey

Keywords

Daylighting, Illuminance, Educational buildings.

Abstract

Integrated lighting design is significant in terms of support energy performance and users visual comfort without expensive energy cost and comfortable environment in buildings illuminated by daylight. This study examines the illuminance levels of two chosen classrooms in the Department of Architecture at Niğde Ömer Halisdemir University. Both classrooms were oriented in north direction, and one of them is one storey above of the other one. The purpose of the study is to determine the lighting performance of classrooms with or without the utilization of artificial lighting. Illuminance levels were measured at certain points by a luxmeter at three different times of the day for five weeks duration. After, average illuminance levels were determined for both classrooms and these illuminance levels were evaluated based on lighting standards. Chosen classrooms were examined regarding their illuminance levels. Measurement results show that the illuminance values in D205 classroom on the first floor was slightly higher than the D105 classroom on the ground floor. Based on the measurements, it was realized that the highest illuminance values were generally at midday (1386 lux at D205) and the lowest illuminance values were in the morning (64 lux at D105). The study will contribute to the formation of a preliminary idea about the lighting performances in the classrooms of architects and architecture students.

1. Introduction

Lighting is one of the most important elements in the physical environment. Because one of the basic principles that ensures the use of lightning in the areas in order to make them healthy and comfortable by applying enough light and lighting. Good and quality lighting can be defined as being able to see all the details required by the quality standards in both indoor environment quality and human health and in the work done is important in terms of time and energy saving and efficiency [1]. Appropriate design of lighting in educational buildings and sufficient and homogeneous distribution of light in the space are of great importance in terms of student performance. In the context of global warming and decrease on natural energy resources, it is principal to concentrate on reducing energy consumption in buildings especially in educational buildings regarding their necessity of great lighting energy [2].

There are various studies in literature related to examine lighting performance of buildings [2-9]. Besides, lighting performance of educational buildings is significant in order to be analyzed. Some of the educational buildings were studied by researchers in the literature [10-16].

There are very few studies on integrated lighting performance with or without artificial lighting performance. Moreover, there are few studies especially lighting performance of university buildings. On the other hand, lighting design was tought an elective course in the architecture departments of many universities.

* Corresponding Author: Tuğba İnan Günaydın
E-mail address: tinan@ohu.edu.tr, ORCID: https://orcid.org/0000-0003-0861-4835

Received: 09 May 2023; Revised: 15 May 2023; Accepted: 17 May 2023
https://doi.org/10.61186/crpase.9.2.2846

Academic Editor: **Vahid Najafi Moghadam Gilani**

Please cite this article as: T. İnan Günaydın, Investigation of Illuminance Levels of Classrooms on Different Storey with or without Artificial Lighting, Computational Research Progress in Applied Science & Engineering, CRPASE: Transactions of Civil and Environmental Engineering 9 (2023) 1–7, Article ID: 2846.

Understanding the behavior of buildings with or without artificial lighting is significant that needs special consideration and research. In this study, illuminance levels were measured at 16 points using a luxmeter in three different times of the day for five weeks duration in both classrooms. Afterwards, average illuminance levels were determined for both classrooms, and these illuminance levels were evaluated based on lighting standards. Measured illuminance levels were compared on both classrooms for all daytime measurements with or without artificial lighting. Chosen classrooms were examined in detail regarding their illuminance levels with or without artificial lighting. The aim of this study is to examine the effect of storey level and artificial lighting on illuminance levels for all measurement conditions.

2. Daylighting

Daylighting is a kind of passive strategy to improve energy performance and users visual comfort without additional expensive installation and operational cost [17]. It is essential to provide an efficient and comfortable environment in buildings illuminated by daylight which is the most basic light source during the day. It is believed that “learning”, the most basic action that takes place in educational structures, is directly related to daylight, and daylight helps students keep their minds active during classroom learning activities. In relation to the purpose of using the classroom, the visual comfort conditions necessary for users should be provided with a static, stationary, and evenly distributed illumination. To have the desired level of visual comfort conditions; it is necessary to improve visual and spiritual performance, to keep learning performance steady in high levels, to increase self-motivation and productivity. In addition, with a sufficient level of illumination, the feeling of fatigue can be reduced by allowing users to see and perceive the environment comfortably.

2.1. Guidelines and Recommended Values for Daylighting in Educational Buildings

There are various standards and regulations that present the precautions and conditions for good daylighting in buildings [18-22]. Green building rating system from the US Green Building council, suggests a Daylight factor (DF) of 2% for the minimum daylight level and a minimum illuminance level of 269 lx on the equinox at 9 am and 3 pm under the International Commission on Illumination (CIE) clear sky conditions [23]. The environmental rating system BREEAM awards a credit in which occupied spaces have an average DF of over 2% [24]. The Illuminating Engineering Society of North America (IESNA) committee promotes an illuminance level of 300 lx for offices, classrooms and library type spaces, occupied hours from 8 am to 6 pm local clock time. Uniformity in the illuminance is a significant criterion in daylighting. General guidelines tend to include an illuminance uniformity criterion (e.g. minimum to average of 0.7 over the area of work) [22]. According to Chartered Institution of Building Services Engineers (CIBSE), in educational buildings, the minimum illuminance level is 300 lx for classrooms and computer practice rooms whereas the minimum illuminance level is 750 lx for technical drawing classrooms and 500 lx for conference and meeting rooms [25].

Illuminance levels, daylight factor, uniformity ratio, window wall ratio (WWR) and window floor ratio are the basic parameters in purpose to evaluate daylighting performance of a space. Ne’eman and Hopkinson (1970) stated that the combined windows should provide an average 5 % DF for a substantial part of the floor space. From the architect’s viewpoint, this may appear to be the most important decision in determining the appearance of the building elevations from the exterior. On the other hand, from a strategic point of view, it will determine the success of the daylight-based design approach. They determined that acceptable window width was directly proportional to a participant’s distance from the window (i.e. the further one sat away from the window the wider one preferred the window). They find a window value of 35% percent of window wall. [26]. Keighley’s (1973) study showed that the windows occupying 10 % or less of the window wall were regarded as extremely unsatisfactory. The size of windows

20 % of the wall were substantially small;however, it was in the acceptable level. The result of the study suggested that 20-30 % is appropriate for providing satisfaction of the building occupants [27]. Fontoynont and Berrutto (1997) stated that the ratio of the glazed area to the floor area is called as glazing ratio. Besides, this ratio approximately ranges from 5 to30 % [28]. This is a practical idea for an understanding of general brightness of the space over the year. When the windows are confined to one-sided only, it is recommended that the total widths of the windows should be at least 35 % of the length of the wall [19].

3. Research Methodology

In this study, the illuminance level of classrooms designated as 105 and 205 in Niğde Ömer Halisdemir University Central Campus Faculty of Architecture were investigated. The chosen classrooms are in the left wing side of the building. The effect of artificial lighting and natural lighting on the level of illumination have been examined in detail. The locations of the classrooms are illustrated in Figure 1 and 2.

Figure 1. The font view of Niğde Ömer Halisdemir University, Faculty of Architecture

Figure 2. Layout of Faculty of Architecture

Interior views from both classrooms are exhibited on Figure 3. The existing lighting element in the classroom is with a dimension of a 60x60 cm surface-mounted double parabolic fluorescent luminaire providing white light. The ceiling lighting plan is illustrated on Figure 4.

Classroom 105

Classroom 205

Figure. 3 Chosen classrooms for measurements

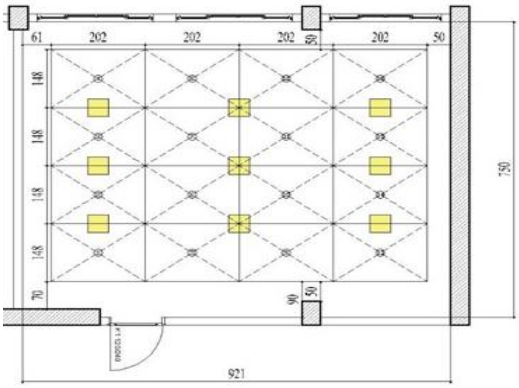

Figure 4. Ceiling lighting plan

In order to measure illuminance values for the classrooms, a luxmeter, Testo 545 is utilized. The light level measurement range of the luxmeter is from 0 lx to 100000 lx. To find the illumination values in each chosen classrooms, a room index (R) is calculated as the first step. The room index is the number that describes the ratios of the rooms length, width and height where L is the room length, W is the room width and Hm is the mounting height of fitting from working plane, as in Eq. (1) [25].

$$R = (LxW)/Hm(L + W). \quad (1)$$

The result of this calculation will be a number usually in between 0.75 and 5 according to the CIBSE Code for Interior Lighting. Based on this room index (R), the number of points is displayed in Table 1. This room index will be used in the following part for dividing classrooms into an equal area that should be as square as possible.

Table 1. Number of measurement points to determine illuminance levels

Room Index	Number of points
Below 1	9
1 and below 2	16
2 and below 3	25
3 and above	36

The room index is found 1.37 for both classrooms. Therefore, considering this room index, 16 measurement points are found to be enough for both Classrooms 105 and 205. The CIBSE Code recommends that the measurements is to be taken at least 0.5 m away from the walls and this must be taken into account in positioning the grid points [25]. This rule is applied to the the chosen classrooms. Illumination levels are determined at the working plane 0.80 m above the finished floor. Illumination values are measured in the measurement grid at the center of the grid in which the measurement points are defined previously. These points are shown on Figure 5. The general information of the classes related to the measurement points are displayed in Table 2.

Almost half of the measurements were taken in clear-sky conditions, while the others were measured in overcast-sky conditions. The sky conditions during the measurement day and time are given in Table 3.

Table 2. General information about classrooms

	Classroom 105-205
Classroom length	9.21 m
Classroom width	7.50 m
Classroom height	3.80 m
Work surface	0.80 m
Room index	1. 37
Number of measurement points	16
Windows width	2.50 m
Windows height	2.50 m
Number of windows	3
Height of windows above floor	80
Glazing area	18.75 m^2
Floor area	69 m^2
Glazing ratio	27%
Window orientation	One sided-North

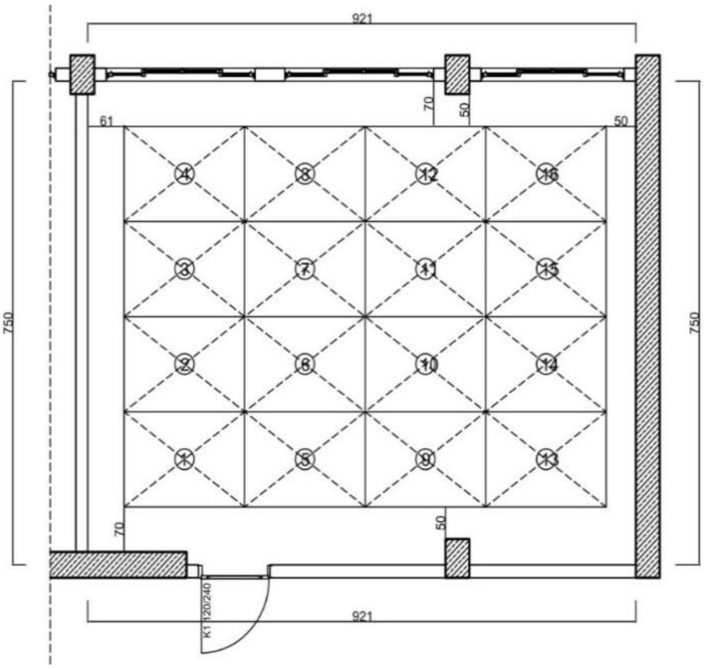

Figure 5. Measurement points in Classroom 105 and 205.

Table 3. Sky conditions on measurement days

Date/Time	8.30-9.30	12.00-13.00	15.00-16.00
29.11.2021	clear	clear	overcast
6.12.2021	clear	clear	clear
13.12.2021	overcast	clear	clear
20.12.2021	overcast	overcast	overcast
27.12.2021	overcast	overcast	clear

4. Results and Discussion

The analysis results are discussed according to average of illuminance levels of five-day duration measurements. The results from the measurements are examined comprehensively in this part. In this study, the illuminance levels were measured at 16 points using a luxmeter in three different times of the day for five weeks duration in both classrooms. The classrooms were oriented to north direction and one is in the ground floor and the other is one storey above of it. The average illuminance levels were determined for both classrooms and these illuminance levels were evaluated based on lighting standards. According to investigated lighting standards, the minimum average of illuminance level recommended for the classrooms was 300 lx. The aim of this study is to examine the effect of storey level and artificial lighting on illuminance levels. In line with the study, measured illuminance levels were compared on both classrooms for all daytime measurements with or without artificial lighting. Chosen classrooms were examined in detail regarding their illuminance levels with or without artificial lighting. The average values of illuminance levels for all conditions are displayed in Table 4.

Table 4. Measurement results in Classroom D105 and 205

E_{ort} (lux)												
Classroom	**D105**						**D205**					
Time	8.30-9.30		12.00-13.00		15.00-16.00		8.30-9.30		12.00-13.00		15.00-16.00	
lamp	lamp of	lamp on	lamp of	lamp on	lamp of	lamp on	lamp of	lamp on	lamp of	lamp on	lamp of	lamp on
29.11.2021	308	534	872	1280	412	694	357	731	1162	1386	375	609
6.12.2021	304	525	450	706	545	827	306	568	411	746	549	883
13.12.2021	98	377	641	883	459	703	238	581	670	933	487	781
20.12.2021	188	448	791	975	151	423	125	453	236	436	190	492
27.12.2021	64	339	701	984	437	702	84	386	797	1097	431	688

In the morning and afternoon measurements, it was observed that sufficient illumination level was not provided in the classrooms when the lamp was turned off in overcast sky conditions. Besides, in the measurements performed in overcast-sky conditions, it was observed that the minimum average illuminance level was achieved at all measurement time intervals with the lamp turned on. In almost all of the measurements made at midday, it was observed that sufficient illumination level was provided in the classrooms when the lamp was turned off for all sky conditions. In all measurements made under clear sky conditions, it was observed that the minimum average illuminance level was more than achieved even when the lamp was turned off (Table 4 and Figures 6-9).

In the morning measurements performed in the 3rd, 4th and 5th weeks, it was observed that the illuminance level was insufficient in both classrooms when the lamp was turned off due to the overcast sky. In general, when the measurements performed in the morning are examined, it is seen that the maximum illuminance level attained when the lamp is on731 lx at D205 classroom on clear-sky condition and the minimum illuminance level attained when the lamp is off being 64 lx at D105 classroom under overcast-sky condition. In the morning measurements, higher illuminance levels were measured in the classroom D205 which is on the first floor, one more storey above than the classroom D105 on the ground floor. (Table 4 and Figures 6-9). According to the results of the research by Abdullah et al. [29], these low values are normal due to the overcast-sky conditions. They found an illuminance level as low as 13 lux in their morning measurements in classrooms facing northwest. It is also consistent with the measurements in this study.

In the midday measurements, it was determined that the average illuminance level was achieved but in the 4th week when the light was turned off, the average illuminance level in the D205 class was 236 lx at midday. This is due to the instantaneous change of sky condition during measurement. Because, in the measurements made at noon, even when the lamp is turned off, sufficient illumination level is provided comfortably, except for this situation. In the measurements made at midday, the highest average illuminance level was observed as 1386 lux in the D205 classroom when the lamp was on under clear sky conditions (Table 4 and Figures 6-9).

In the measurements made in the afternoon, it was observed that the average illuminance level was insufficient in both classrooms in the 4th week when the lamp was turned off due to the overcast sky. The minimum average illuminance level was observed as 151 lx in the D105 (Table 4 and Figures 6-9).

When all the measurements made at three different times of the day for five weeks were examined, it was determined that the highest illuminance level values were generally at midday and the lowest illuminance levels were in the morning. Moreover, when the illuminance values were compared both D205 and D105 classrooms, it could be said that the illuminance values in the D205 classroom on the first floor was slightly higher than the D105 classroom on the ground floor (Figures 7-8).

When all measurements were evaluated, it was realized that the highest illuminance level values were obtained in the measurements made at midday, and the lowest illuminance level values were obtained in the measurements made in the morning. In addition, a significant increase in the illuminance level values was observed in both classrooms with the lamp turned on. Moreover, the increase in the illuminance levels were observed more clearly in the midday measurements (Figure 9).

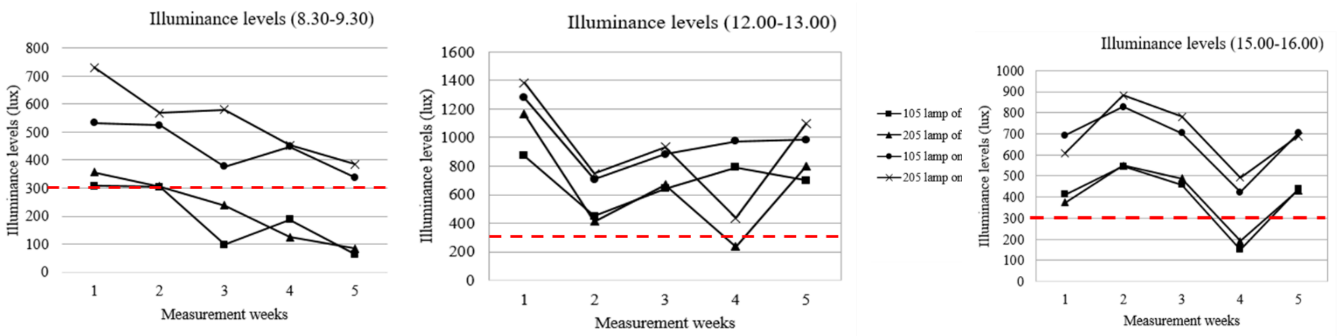

Figure 6. Average illuminance levels on daytime

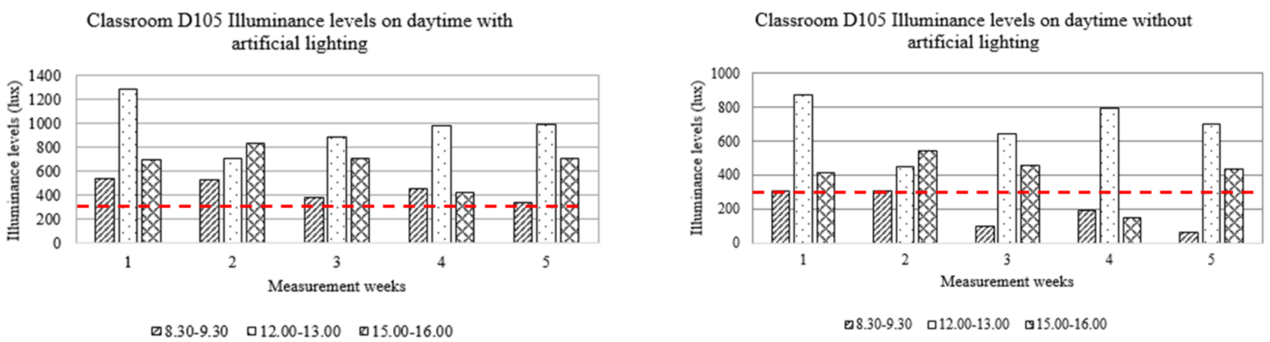

Figure 7. Average illuminance levels at Classroom D105 on daytime with or without artificial lighting

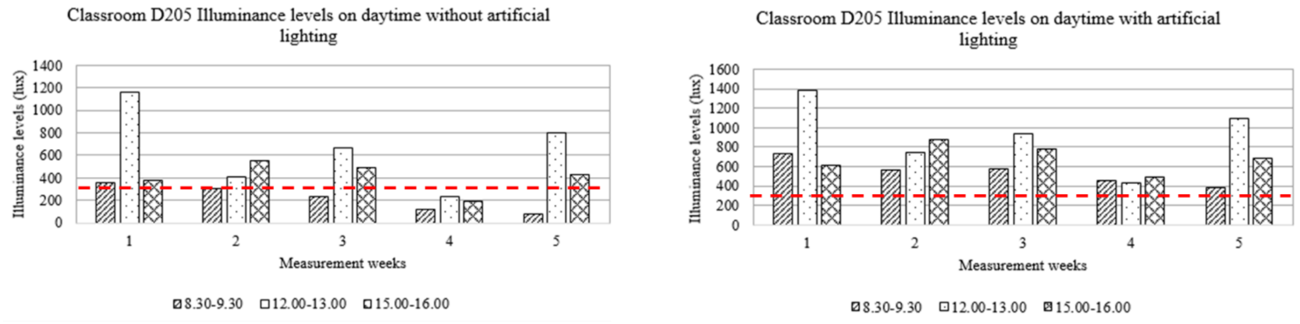

Figure 8. Average illuminance levels at Classroom D205 on daytime with or without artificial lighting

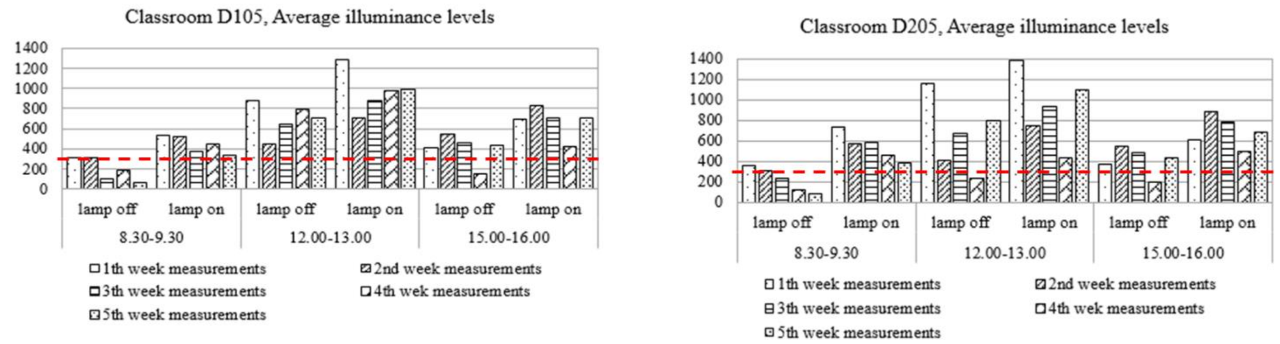

Figure 9. Average illuminance levels on both classrooms

5. Conclusions

This study examines illuminance levels of two chosen classrooms in the Department of Architecture at Niğde Ömer Halisdemir University, which is the northern hemisphere. The classrooms were oriented to north direction and one of them is one storey above the other. The purpose of the study is to determine the lighting performance of classrooms with or without artificial lighting. Daylight standards promotes an illuminance level of 300 lx for classrooms in general. In this context, classrooms were examined in detail.

According to the measurement results, it was determined that the highest illuminance level values were generally at midday and the lowest illuminance levels were in the morning. Measurement results show that illuminance values on D205 classroom on the first floor was slightly higher than the D105 classroom on the ground floor. Based on the measurements, it was realized that the highest illuminance value was 1386 lux at midday in class D205 and the lowest illuminance value was as 64 lux in the morning at class D105. In addition, a significant increase in the illuminance level values was observed in both classrooms with the lamp turned on. For instance, in the morning measurement, the illuminance level, which was measured at 64 lux when the lamp was off, increased to 339 lux when the lamp was turned on. In the afternoon measurements, the illuminance value was measured as 151 lux when the lamp was off and increased to 423 lux when the light is turned on. Moreover, the increase in the illuminance levels were observed more clearly in the midday measurements. In the measurements, the highest average illuminance level was observed as 1386 lux in the D205 class when the lamp was on under clear sky conditions at midday and the lowest average illuminance levels attained as 64 lx in the D105 classroom when the light was off under overcast-sky condition. On the other hand, when the illuminance values were compared both D205 and D105 classrooms, it could be said that the illuminance values in the D205 classroom on the first floor was slightly higher than the D105 classroom on the ground floor. It can be said that the limit value of the illuminance level is generally provided in both classes. In the morning measurements, it was observed that illuminance values were close to the limit value of 300 lux even when the lamp was on.

References

[1] K. Çelik, F.R. Ünver, Eğitim yapılarında sürdürülebilir aydınlatma tasarımı yaklaşımı, Çukurova Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi 34(2019) 49–64.

[2] T. Inan, An investigation on daylighting performance in educational institutions, Structural Survey 31(2013) 121–138.

[3] F. Piraei, B. Matusiak, V.R. Lo Verso, Evaluation and Optimization of Daylighting in Heritage Buildings: A Case-Study at High Latitudes, Buildings 12(2022) 20–45.

[4] M. Rastegari, S. Pournaseri, H. Sanaieian, Analysis of daylight metrics based on the daylight autonomy (DLA) and lux illuminance in a real office building atrium in Tehran, Energy 263(2023).

[5] Y. H. Teo, J. H. Yap, A. Hui, N. Xie., J. Chang, S.C. M. Yu, K.H. Cheong, A simulation-aided approach in examining the viability of passive daylighting techniques on inclined windows, Energy and Buildings (2023).

[6] F. Favero, A. Lowden, R. Bresin, J. Ejhed, Study of the Effects of Daylighting and Artificial Lighting at 59° Latitude on Mental States, Behaviour and Perception, Sustainability 15(2023).

[7] V. Cimino, M. Frascarolo, M. Mucciante, U. Santamaria, Interaction between daylighting and artificial lighting in relation to conservation and perception, according to new

illumination system of Sistine Chapel, Journal of Cultural Heritage 58(2022) 256–265.
[8] B.S. Qurraie, Smart Window Design Tool: Daylight Transmission by Using Transparent Color Filters, CRPASE: Transactions of Civil and Environmental Engineering 8(2022) 1–10.
[9] B.S. Qurraie, F. Beyhan, Investigating the Effect of Stained-glass Area on Reducing the Cooling Energy of Buildings (Case Study: Ankara), CRPASE: Transactions of Civil and Environmental Engineering 8(2022) 1–11.
[10] M. Wang, D.X. Chen, Z.H. Zhang, Q. Ma, Y.C. Ren, Research on parametric optimization of daylighting in university teaching building. In 5th International Conference on Advanced Electronic Materials, Computers and Software Engineering (AEMCSE) IEEE
April (2022).
[11] I. Ghonimi, Assessing daylight performance of single vs. double skin facade in educational buildings: A comparative analysis of two case studies, Journal of Sustainable Development 10(2017) 133–142.
[12] B. Abdelatia, C. Marenne, C. Semidor, Daylighting strategy for sustainable schools: case study of prototype classrooms in Libya, Journal of Sustainable Development 3(2010).
[13] M.M. Samaan, O. Farag, M. Khalil, Using simulation tools for optimizing cooling loads and daylighting levels in Egyptian campus buildings, HBRC journal 14(2018) 79-92.
[14] D. Saha, S. Ahmed, A.T. Shahriar, S.N.H. Mithun, North-south vs east-west: the impact of orientation in daylighting design for educational buildings in Bangladesh, Architecture Research 7(2017) 184–189.
[15] V. Costanzo, G. Evola, L. Marletta, A review of daylighting strategies in schools: state of the art and expected future trends, Buildings 7(2017) 41.
[16] W. Wu, E. Ng, A review of the development of daylighting in schools, Lighting research & technology, 35(2003) 111–124.
[17] Y.W. Lim, M.Z. Kandar, M.H. Ahmad, D.R. Ossen, A.M. Abdullah, Building facade design for daylighting quality in typical government office building”, Building and Environment 57(2012) 194-204.
[18] British Standards Institution (BSI), BSI Standards Catalogue, London, 1992.
[19] BS 8206-2,British Standard”, Lighting for buildings. Part 2: Code of practice for daylighting, 2018.
[20] Hong Kong Government Laws of Hong Kong Chapter 123 Building (Planning) Regulations – Lighting and Ventilation, Hong Kong Government, Hong Kong, 1997.
[21] Buildings Department, HKSAR, Lighting and Ventilation Requirements Performance-Based Approach, Practice Note for Authorized Persons and Registered Structural Engineers PNAP278, The Government of the Hong Kong Special Administrative Region, Hong Kong, 2005.
[22] Illuminating Engineering Society of North America (IESNA), Lighting Measurement Spatial Daylight Autonomy, Illuminating Engineering Society of North America, New York, 2011.
[23] USGBC, LEED-NC Leadership in energy and environmental design, 2009.
[24] BREEAM, BRE Environmental & Sustainability Standard, BES 5056, issue 2.0, London, 2008.
[25] Chartered Institution of Building Services Engineers (CIBSE), Code for Lighting, Guide A, 7th ed., CIBSE, London, 2006.
[26] E. Ne'Eman, R.G. Hopkinson, Critical minimum acceptable window size: a study of window design and provision of a view. Lighting Research & Technology 2(1970) 17–27.
[27] E.C. Keighley, Visual requirements and reduced fenestration in office buildings—A study of window shape. Building science 8(1973) 311–320.
[28] M. Fontoynont, Daylight Performance of Buildings, France, Rroutledge, Earthscan, 1999.
[29] A.H.A. Tharim, W.N.H.W Abdullah, A. Ismail, A.C. Ahmad, Determination of Design Solutions to Overcome the Daylighting Design Failure Observed in Existing Educational Building, International Journal of Sustainable Construction Engineering and Technology 13(2022) 153–167.