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Turkish D-Light: Accentuating Heritage Values with Daylight

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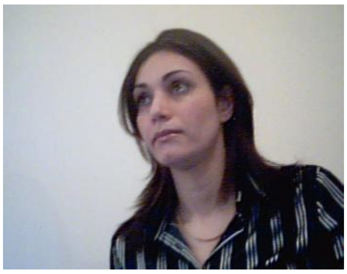

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Abstract

Historic buildings have their own cultural identity, which is often related to their aesthetic qualities, such as period characteristics (geometry, size, colour, form and shape), materials and construction. Daylight is one of the primary elements that have contributed to the distinctiveness of the visual environment of many historic buildings. Yet when adaptive preservation schemes of historical buildings are planned, daylight is rarely considered as one of the components that shape the character of buildings. Many of these buildings were originally designed to accommodate different activities to their new use. Preserving the quality of daylight that originally contributed to their visual identity is a challenging task. Maintaining the "*daylit appearance*" of a building can be particularly problematic if the building is to be used as a museum or a gallery due to artefacts' conservation requirements.

This paper investigates the opportunities of maintaining the original ambient conditions of renovated historical buildings while meeting the required daylight levels of the proposed new use. The paper utilises an annual daylight simulation method and hourly weather data to preserve daylight conditions in renovated historic buildings. The model is piloted in a Turkish bathhouse situated in Bursa, Turkey, that is currently under renovation. The simulation model produces 4483 hourly values of daylight illuminance for a period of full year using the computer program Radiance. The paper claims that daylight characteristics should be taken into account when developing a renovation scheme. With the increasing pressure for valuing historic buildings in many parts of the world, the work reported in this study can be beneficial to those concerned with the conservation practice and the adaptive reuse of historic buildings. The study findings can also be useful to those interested in predicting potential energy savings, combining daylighting and electric lighting in historic buildings.

Keywords

Environment; Rehabilitation, reclamation & renovation; Developing countries

1. Introduction

Several rehabilitation projects of urban centres have been recently implemented in Bursa, the fourth largest city of Turkey. A number of the city's indigenous buildings were converted to museums, art galleries, cultural and community centres. Keeping and reusing historic buildings, a well-supported practice by the Turkish government, is often seen as a way not only to preserve the physical building fabric "*as a tangible link with the past*", but as an opportunity to preserve the intangible heritage such as traditional skills and craftsmanship (Cengiz, 2012). Often, the intention is to provide new accommodations where valuable artefacts can be exhibited and stored. Many of these buildings were originally designed to accommodate different activities to their new use. Preserving the quality of daylight that originally contributed to their visual identity can be a very challenging task. Furthermore, as most historical buildings were originally designed to maximise daylight, maintaining the "*daylit appearance*" of a building can be problematic in terms of artefact conservation requirements. On the other hand, a successful utilisation of daylight can create a better visitor experience and museum environment as well as improve the energy efficiency of a building. In top-lit galleries (in temperate climates) savings in the order of 50% to 60% in installed lighting loads are estimated if daylight is properly integrated with artificial lighting (Carver, 1994).

Museums and art galleries are well recognized for their demanding day/lighting criteria (Kim and Chung, 2011). Museum personnel often face the challenge of illuminating the museum environment while addressing the conservation requirements of museum objects (Hoyo-Meléndeza *et al*, 2011). Whereas retrofitting of ordinary non-historical old buildings can offer a number of possibilities for improving the ambient conditions and energy efficiency of buildings (Baker and Steemers, 2002), in a heritage building, a radical change to the original quality of daylight through an extensive use of artificial light or displacement of daylight can have a critical impact on the visual character and sense of place (Al-Maiyah and Elkadi, 2007). Although the conservation practice in general is clear about the importance of applying and adopting "*minimal intervention*" when developing a rehabilitation scheme, the practice of implementing "*minimal intervention*" is often understood by designers in terms of preserving the tangible aspects of a building. Indeed preserving the original tangible components of buildings such as their materials, fabric and fenestration features, is the key for preserving the physicality of the buildings. There are however many other facets of historical buildings that contribute to their distinctive quality and significance. Daylight is one of these in/tangible elements that have contributed to the distinctiveness of many historical buildings and settlements (Al-Maiyah and Elkadi, 2012). Yet when initiating preservation schemes of historical buildings daylight is rarely introduced as one of the components that shape the character of buildings. A review of relevant documents suggests that at present there is no clear recognition of the role of daylight in shaping the visual character of historical buildings. For example Nelson (2004, p.171), in a chapter published in the U.S. government's official text on saving old buildings, identifies the visual aspects and physical features that comprise the appearance of historical buildings as follows: “*Character-defining elements include the overall shape of the buildings, its materials, craftsmanship, decorative details, interior spaces and features, as well as the various aspects of its site and environment*”. Although the environment, as evident in this quotation, has been identified among the various components that give the building its visual character, the actual description does not provide an explanation of what this term means in relation to the building context, whether it is the surrounding external context or internal ambient conditions. The work is mainly limited to identifying tangible aspects related to the physical characteristics of buildings. Without a clear valuation and an understanding of the value of daylight in shaping the visual character of a historical building, it would be rather challenging to first establish whether daylight should be taken into account when developing a renovation scheme, and then what might be considered as “*minimal intervention*” in terms of preserving its ambient conditions. This paper highlights the importance of daylight in accentuating the distinctiveness of heritage buildings. The pressure on city councils to provide a new usage of large numbers of empty heritage buildings could result in distorted renovation projects. Appropriate analysis of daylight would ensure the continuing celebration of heritage in their contexts as well as improving energy efficiency measures.

2. Daylighting regulations and practice in Turkey

The role daylight can play in improving the energy efficiency in buildings has recently received much attention in energy performance regulations in Turkey. The value of daylight and the importance for maximising its effectiveness for illuminating building interiors, which were clearly stated in building performance legislations introduced in 2008, has been further emphasised recently with the latest introduction of the new Turkish Lighting Standard. As a candidate country for the European Union membership, Turkey has adopted the European Standard Lighting of Work Places (EN 12464-1:2011) in January 2012 as the Turkish Lighting Standard (TS EN12464-1:2011). Item 4.10 of this standard emphasises the role of daylight provision in buildings and provides in clause 5.4 the lighting requirements for retail premises, such as restaurants and hotels, theatres and concert halls, as well as exhibition halls and museums. All of these functions can also guide the re-use of historical buildings. While recommended light levels for most of these public premises are given in the European guidelines, there are no values given for museums, where lighting requirements are mainly determined by the display classification. However, other reliable international guidelines such as those recommended by the Illuminating Engineering Society of North America (IESNA) or by the Charted Institution of Building Services Engineers (CIBSE) can be used (and it is often used in previous similar studies) to establish lighting requirements in a museum or gallery environment. As well as this Turkish-adopted European Standard, there are currently two other legislations in Turkey that include guidelines on building lighting. These are the Legislation for the Effective Use of Energy Sources and Energy Consumption and the Legislation of Energy Performance in buildings, both dating back to 2008 (Erkin *et al*, 2009). However, none of these legislations provide recommendations for lighting levels or illuminance values. With the new Lighting Standard now in place, there is an even better ground or base to measure how traditional buildings perform against these recent requirements. As the recycling of old buildings is a practice well received and increasingly emerging in many other major cities in Turkey, the work reported in this study can be beneficial for those concerned with conservation practice and the reuse of historical buildings in the region.

3. Daylighting requirements in museum buildings

Whilst the presence of natural light with its vibrant qualities is an attractive design feature in many building types, in a daylit museum environment certain preventive measures should be taken to minimise its "*deleterious*" effects on the museum collection. Daylight has always had the most desirable colour-rendering qualities for aesthetic reasons that are important to the museum function. However, the high energy in the Ultraviolet region (UV) of the spectrum can cause chemical and physical damage to the fragile objects in the collection, such as discolouration, fading, yellowing and surface cracking. Unnecessary visual light can also pose a threat to certain types of museum objects. The "*reciprocity law*" states that the cumulative photochemical effect "is directly proportional to the illumination levels multiplied by the time of exposure" (United States Department of Interior, 1999). Thus 200 lux exposure for six months can cause as much damage as 100 lux exposure for one year. Reducing the exposure time is therefore another important measure to limit damage from light. On the other hand, the rate and extent of deterioration brought about by the amount of light and exposure time varies between the different types of objects depending on their material properties and chemical composition.

Museum artefacts in general can be grouped into three categories based on sensitivity to light: highly sensitive objects derived from organic origins, partially sensitive objects containing organic and inorganic substances and insensitive objects having geological origin. The illuminating Engineering Society of North America (IESNA) (2000) established illuminance recommendations and annual exposure times for the various material–type categories found in a museum collection. As illustrated in Table (1), a maximum of 50 lux is recommend for highly sensitive objects and a range of 200 lux and 300 lux for partially sensitive and insensitive objects, respectively. Similar illuminance values are also given in the Charted Institution of Building Services Engineers (CIBSE) Lighting Guide LG8 (1994). In terms of the exposure time, the values given in the IESNA lighting handbook are relatively lower than those given in the CIBSE lighting guide (Table 1). These later values are based on the assumption that the lights will be either extinguished or maintained at a very low level outside museum opening hours. While reducing the length of exposure to light is important in terms of conservation considerations, determining the correct level of illuminance in display spaces is equally important in terms of comfort and visibility. The limits recommended in Table 1 are widely accepted as practical for reducing damage while maintaining adequate view conditions (CIBSE, 1994), and thus adopted in the present study for assessing the annual illuminance values and the total annual exposure to daylight in the selected case study.

Table 1 Maximum illuminance levels and cumulative exposure values given in the IESNA lighting handbook and the CIBSE lighting guide for various types of exhibits

	Maximum illuminance		**Maximum annual cumulative exposure**	
Types of materials	CIBSE Lighting Guide	IESNA Lighting Handbook	CIBSE Lighting Guide	IESNA Lighting Handbook
Objects insensitive to light, e.g. metal, stone, glass, ceramics and most minerals.	Subject to heating and adaptation effects	Depends on exhibition situation	_	Depends on exhibition situation
Objects moderately sensitive to light, e.g. textile with stable dyes, oil and tempera painting, ivory, and wood.	200 lux	200 lux	600, 000 lux-hours	480,000 lux-hours
Objects highly sensitive to light, e.g. textile, costumes, tapestries, prints and drawings, silk, and writing inks.	50 lux	50 lux	150, 000 lux-hours	50,000 lux-hours

4. Methodology

Several site visits to selected heritage buildings (buildings that are recently converted to museums or to be converted to museums) in Bursa took place in May and August 2012 and September 2013 (Figure 1). The selected buildings include the Demirçi bathhouse (a small bathhouse currently under renovation), the Uluumay museum (an old religious school that became a museum in 2000), the Ordekli bathhouse (converted to an art and cultural centre in 2008). The Muradiye Madrasa (an old school) is soon to be also converted to a museum. The new use of the Demirçi bathhouse is a cultural centre where art exhibitions can be organised regularly to benefit the village’s community. The building offers therefore an opportunity to test the possible use of its original ambient daylight conditions for a better adaptive reuse strategy.

Until recently daylight studies of buildings have mainly focussed on assessing the illuminance values received into a building or part of a building on selected seasonal dates and times of day. Key seasonal dates that are often used for performing such analysis are the winter and summer solstices and the fall and spring equinoxes. Since the early 2000s, an increasing number of authors have argued the limitation of such approach and advocated for a more realistic systematic approach of evaluation, preferably hourly annual evaluation (Mardaljevic, 2000; 2006; Mardaljevic *et al*, 2011; de Hoyo-Meléndeza et al, 2011).

The revised methodology using annual evaluation of daylight illuminance levels is essential in daylight studies of museums and exhibition buildings given the sensitivity of artwork objects to excessive exposure to illuminance levels. Since natural illuminance values are mainly affected (among other things) by the sky conditions and the thickness of the sky cover, it is important to separate between the various sky conditions and choose the right sky type for each step/hour of the evaluation. For this reason, Bursa sky conditions are classified into three types using hourly cloud cover data obtained from a standard weather file for the city (ASHRAE IWEC weather file for Bursa).These are clear sky (has less than 30% cloud cover), partly cloudy sky (cloud cover ranges between 30% and 70%) and overcast sky (more than 70% cloud cover). The classification of the sky types presented here is in line with the CIE definitions of standard general sky models and the use of this hourly statistical based approach is similar to a previous work by Tzempelikos and Athienitis (2005). Then, hourly daylight simulations for a period of one year were performed to calculate annual illuminance values received into the selected bathhouse using existing CIE models for clear, overcast and intermediate sky conditions in the IES Virtual Environment Radiance.

Bursa is located in north-western Anatolia within the Marmara Region between 40°11′ north latitude and 29°03′ east longitude. The city has a Mediterranean climate with dry hot summers and an average of 14 hours of daylight and mild winters with an average of 9 hours of daylight. However the classification of the sky conditions using the cloud cover data presented above reveals a total number of 1945 hours of clear sky conditions in Bursa, 1362 hours of mixed sky conditions and 1322 hours of overcast conditions during daylight hours per year. An illustration of the average annual direct normal illuminance received by the city in units of lux hours according to the weather file used in the study is shown in Figure 2. As illustrated in the matrix the amount of direct normal illuminance received by the city from the solar disk over the summer period (June to September) can be as high as 39,000 lux hours. Thus, rehabilitation projects (in the region) that seek recycling of historical buildings to re-function as museums, should take advantage of the availability of such high level of illuminance while controlling its contribution to the overall visual environment of the buildings.

Radiance is well known as a powerful and highly accurate modelling tool. Several previous studies with similar content to this work have used Radiance to assess daylight levels and visual comfort criteria in reused historical buildings. Al-Sallal and Dalmouk (2011), for example, used Radiance in their evaluation of the daylighting performance of one of the traditional residential buildings in UAE that was converted to a museum. Daylight levels and ambient conditions in the present town hall in Florence (Palazzo Vecchio), where some of the most precious and ancient tapestries are exhibited, were also examined using a Radiance modelling tool (Balocco and Frangioni, 2010). A three dimensional digital model of the bathhouse was therefore developed using the geometry model creator (Model IT) in the Virtual Environment and the daylight simulation package Radiance was used to perform the annual illuminance evaluation. Reflectance values used for the internal walls and the ceiling including the domes were 50% and 70%, respectively and a reflectance of 20% was used for the floor. These figures were established based on description of the original surface finishes identified in the restoration report that was submitted by the team for planning permission.

In many building types such as in office buildings and schools daylight studies are usually performed by calculating the horizontal illuminance values on the work plane where most of the visual tasks take place. In exhibition halls, by contrast, where some artwork can only be mounted to the walls either vertically or horizontally, evaluating the distribution of daylight on the vertical surfaces of a room is as important as evaluating the values of work plane illuminance. For this reason, an internal view with a fixed camera position that shows the various zones illuminated with daylight within a selected room in the bathhouse was chosen for the evaluation (Figure 3). A series of reference points that were assembled on five main axes on the south, north and west –facing walls of the room was then used to predict the hourly values and the total exposure to illuminance during daylight hours (5 a.m. – 7 p.m. in summer and 8 a.m. – 4 p.m. in winter). The points were situated on sections of the walls that are likely to be used for exhibiting the artworks at three different heights; 0.70 m above the floor, 1.45 m and 2.2 m. The simulation model produces 4483 illuminance values for every calculation point.

5. The Case Study Building: The Demirçi Bathhouse

The plan of the Demirçi bathhouse or hammam follows the traditional layout of the Roman baths with a cold room, a semi-hot room and a hot area (Figure 4). The cold room known as the “frigidarium” is usually used as a transitional space between the changing rooms and the heated area. The semi-hot room known as the “tepidarium” is the room where beauty treatments such as oiling and massaging of the body take place, while the actual bathing takes place in the hot room “caldarium” that is often considered the most important place in a bath building. Traditionally, a bathhouse was both a “*complex structure and an expensive enterprise*” that was carefully designed and perforated to maintain certain ambient conditions necessary for the bathing requirements taking place (Salam-Liebich, 1983). Hence, and like many other hammams, there are no windows in the Demirçi hammam to avoid drafts, save and control steam and heat and daylight is provided by small glass openings studding the domes while allowing a minimum amount to filter through (Figure 1). Today, only the hot area of the Demirçi hammam has survived, as the other two areas (the cold and semi-warm) were destroyed and rebuilt later. These additions which were demolished and rebuilt will be re-functioned along with the original hot complex as a cultural centre as stated before. The dimensions of the caldarium are 7.21 m x 8.77 m, including two hot rooms, a small cell for private bathing and the furnace room (Figure 4).

Table 2 Annual total illuminance received by the three examined walls

	South 1a	South 1b	South 1c	West 1a	West 1b	West 1c	West 2a	West 2b	West 2c	West 3a	West 3b	West 3c	North 1a	North 1b	North 1c
Jan	21820	19909	16753	21937	17333	14224	28505	20268	15796	22426	17959	14616	25971	20770	17011
Feb	21010	25262	21274	28146	22129	18158	35478	25352	19825	27116	22274	18171	32780	25804	21469
Mar	41762	35102	29931	39163	31037	25617	50547	36139	27924	39974	32014	25958	46186	36518	30387
Apr	51183	45134	38481	49583	39642	33229	64079	46151	36751	63799	48708	34360	82306	60975	39020
May	54913	48880	42617	53120	43416	37094	89086	52207	42240	52590	82644	48692	61621	58025	56905
Jun	50266	44166	38313	49780	39879	33634	104831	48454	38940	48202	47505	42716	55789	48781	43393
Jul	48727	41531	35842	47148	37444	31676	63866	45665	35948	46558	70565	37377	54112	45531	38961
Aug	48644	43150	37236	45857	37876	32229	61229	46053	36523	58555	71965	39289	80020	70192	38934
Sep	37251	31571	27218	35083	28238	23475	46568	33351	25818	52901	32868	24578	61610	35995	28711
Oct	32097	27023	22720	30199	23978	19728	38759	27588	21443	31634	25572	20380	37059	29046	23541
Nov	26565	22313	18833	24549	19669	16154	31255	22616	17523	24434	20357	16535	29155	23142	19204
Dec	22007	18410	15453	20417	13339	13339	25851	18678	14553	20137	13683	13683	23787	19128	15814
Total	**456245**	**402451**	**344671**	**444982**	**353980**	**298557**	**640054**	**422522**	**333284**	**488326**	**486114**	**336355**	**590396**	**473907**	**373350**

6. Results and analysis

The transformation of heritage buildings to adopt new uses has challenged the possible maintenance of their original characteristics. Daylight is clearly a key ingredient of such transformation, particularly when the new use includes exhibitions of artefacts. The Demirçi hammam is an excellent case study to carefully study the possible use of daylight not only to sensitively illuminate the artefacts but also maintain the identity and ambience of such a wonderful heritage building.

The year round hourly measurements have provided more accurate representation of daylight performance in the building. The dome of the hammam provides interesting temporal daylight distribution throughout the year. The interesting setting allows for testing the diverse daylight pattern on the north, south and west-facing walls. The distribution of dome - lit daylight greatly differs through the year (Figures 5) but provides steady levels of daylight on the surrounding walls.

Analysis of daylight levels on the three walls shows the possibility of maintaining acceptable levels of daylight within the safety levels (480,000 lux.hrs) for moderately sensitive exhibits such as oil painting, fresco, ivory, and wood. A further in depth investigation revealed particular times at particular points on the walls when precautions need to be taken. While the overall cumulative illuminance falls within the accepted range, contact with illuminance that exceeds maximum exposure levels (200 lux) at any particular time could cause serious damage to the exhibits.

All points at the south wall appear to receive acceptable levels of illuminance exposure all year around. The average monthly illuminance remains under 140 lux (Figure 6). The accumulative levels similarly fall well within the 480,000 lux.hrs limit all year around (Figure 7). As shown in Table 2, the accumulative illuminance values received by the upper section of the wall, the centre section and its lower area range between 456,000 and 350,000 lux.hrs.

The north-facing wall receives a maximum monthly average illuminance of 220 lux in its upper part during April (Figure 8). The upper part of the wall seems to be the only section that would require attention during April and August if sensitive objects are to be exhibited. Similar results were also obtained for the accumulative illuminance. The presence of direct normal illuminance at this particular point and time of the year can be as high as 80,000 lux resulting in accumulative values well above the safety limits recommended for moderately sensitive objects. Precautions are therefore to be taken to avoid exhibits placed on the upper part of the wall and the middle section during August (Table 2). Showcases equipped with ultraviolet protective coatings can add another level of safety in spots where might be a concern about the level of daylight.

The west-facing wall is a long running wall and provides a convenient surface for exhibition of artefacts. For testing purpose, the wall was therefore divided into three parts; left, centre, and right sections. The analysis of the left side of the west facing wall shows no reason for concern (Figure 9). The maximum monthly average was again mostly under 120 lux except for a slight increase during April in the upper part of the wall where the average value predicted was 135 lux (Figure 10). The annual accumulative exposures were also under the 480,000 lux.hrs limits allowing for unconstrained usage of the wall for exhibition of moderately sensitive materials (Table 2). Similarly, the centre part of the west facing wall shows higher illuminance level during summer period, particularly 25 May to 25 June, on the upper part of this section (Figure 11). The right side of the west facing wall has however much higher level of illuminance for the middle part of the wall for a longer period of the year (May-August).

On a monthly basis, the central section of the three selected walls of the room (Point b which is located at 1.45 m high) seems to receive an average illuminance of 60 to 90 lux between September and February and about 110 to 130 lux between March and August. These figures fall well within the 50 to 200 lux comfort criteria range set by CIBSE and IESNA stated earlier. However, if the upper limit of the range is to be met the maximum intensity of additional lighting needed to compensate for the lack in daylight is 140 lux in winter (December –January) and about 70 to 110 lux in the rest of the year. This additional lighting can be provided as part of the design of display containers and thus should be carefully adjusted depending on the season in order to prevent dramatic changes to the ambiance of the space. As much as blocking the access to daylight can affect the visual perception of the room (as seen during the site visit to the Uluumay museum where daylight openings were fully blocked and replaced by artificial lighting), adding unnecessary artificial lighting can similarly alter the ambient conditions of the place and thus its visual perception. Carefully integrating daylight and artificial lighting can thus not only assist in preserving the art objects and maintaining the original daylight conditions of this heritage building but also can contribute to improve its energy efficiency. A reduction in the use of artificial electric lighting would provide savings in energy bills. The current practice of entirely blocking daylighting to protect the museum artefacts not only modifies the ambience of a heritage building but also increases energy bills.

4. Conclusions

Daylight is a key ingredient for maintaining the identity of a cultural built heritage. In Bursa, intervention to adapt cultural built heritage to more contemporary use is essential for their sustainability. Such intervention cannot just rely on the new Turkish lighting standards, particularly where museums are suggested as new functions for these buildings. The paper shows that a thorough evaluation of the seasonal variation of daylight and careful distribution of artefacts, in a heritage building, not only maintains its ambience and character but also assists in protecting the exhibited objects by limiting the damage caused by excessive exposure to daylight. The outcomes of the simulation of Demirçi hammam highlight the importance of yearly daylight measurements rather than analysis on the base of sample dates data. The particular structure of this building together with daylight through the dome structure necessitates accurate investigation of the dynamic profile of daylight across various wall surfaces. The results also clearly show the possibility of using daylight across many walls of the building to exhibit sensitive objects and artefacts. The results would maintain the ambience and the original experience of the building despite the strict light requirements of the new use.

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Figure captions

Figure 1. The Demirçi Bathhouse (upper images); internal views of the hammam showing the toplit dome of the studied northern hot room, the Uluumay Museum (bottom left), and the Muradiye Madrasa

Figure 2. Annual direct normal illuminance received in Bursa in units of lux hours

Figure 3. Location of the digital sensors used in the analysis; the sensors are placed where objects are likely to be mounted at different heights, 0.7m above the floor (point c), 1.45m (b) and 2.2m (a)

Figure 4. Plan of the hammam showing the heated area in the middle, the cold and warm areas on the west side on the building; the red cross-section line indicates the position of the camera used in the simulation, (right) digital model of the historic section of the hammam

Figure 5. Interior views of the studied northern hot room showing the seasonal variation in daylight levels at a particular point in time (10.00 am) and on a specific day (the 14th of every month) - January to December. The scale bar on the left side of each false-colour rendering was fixed between 0 and 200 lux in order to illustrate the difference in illuminance values

Figure 6. Average monthly illuminance received by the three sections of the southern wall

Figure 7. Daily total illuminance received by the southern wall between January 1st and December 31st

Figure 8. Average monthly illuminance received by the three sections of the northern wall

Figure 9. Average daily illuminance received by the (left side of; reference points west 1a, west 1b and west1c) the western wall between January 1st and December 31st

Figure 10. Average monthly illuminance received by the three sections of the left side of the western wall

Figure 11. Average monthly illuminance received by the central section of the western wall