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Araştırma Makalesi / Research Article

Analysis of International Lighting Criteria and Lighting Design in Light-Sensitive Areas

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Abstract

This study examines the amount of light and the quality of the lighting solution, the preservation of works of art, and the perception of museum environments. Illumination of works of art should not be considered as merely meeting the lighting standards of a museum. At the same time, work lighting and ambient lighting must be balanced as a whole. Illumination and brightness levels, screen, and artifact positions must be selected according to precise calculations. For this reason, lighting comfort that does not tire the eyes should be provided for the display and comfortable perception of the works. When considering the annual light exposure period of a work of art, irreversible damage should be considered. For this reason, the level of sensitivity to light is very important when designing lighting in areas where works of art are exhibited. Lighting design depends on the goals and objectives of a project. For all these reasons, light concept selection criteria should be calculated in detail in light-sensitive areas such as museums.

Keywords: Light, photosensitivity, lighting design

1. Introduction

Museums are places or structures where works of art and science or objects useful for art and science are stored, preserved, and permanently or temporarily exhibited. Museum buildings are places where various social activities are held, mostly exhibitions. In this way, museums provide cultural and intercultural interaction. Since the main function of the first modern museums in the 18th century was to exhibit works of art, museum buildings built for this purpose are generally rectangular in plan and all walls are used for display purposes.

In addition to their exhibition functions, museums are also used in research and educational studies. On the other hand, today's museum buildings act like a work of art with their iconic stances and create the center of attention, attracting visitors' attention with the objects exhibited in the interior. Figure 1 shows the Louvre Museum.

Figure 1. Louvre Museum (URL-1)

In the Lighting Standards of Indoor Working Areas, the illuminance level distribution value, the glare value limit, and the color rendering value are determined according to the parts of the workplace and the nature of the work done (Aykal et. al., 2011; Efe and Varhan, 2020; Parlakyıldız et al., 2020).

• Illuminance Level: The amount of luminous flux per unit area (luminous flux density) is called luminous intensity. The unit is luxury. According to the standard; The illuminance level is between 2000-100.000 lux in the open air and between 50-500 lux at night.

• Reflectance Rate: Each surface has a different reflectance size of incoming light. A dark surface absorbs more light than a light surface, that is, reflects less light. The reflectance ratio is found by the ratio of reflected light to incident light.

• Glare: Glare can be caused by direct or indirect light.

a) Direct glare: It occurs when looking directly at the light source and as a result, eye health is damaged.

b) Indirect glare: It occurs as a result of the reflection of light from reflective surfaces and the work done is adversely affected.

• Direct Illumination: It is the illumination of a surface with light coming from a source in a straight line. It is used in workplaces for

fine works that require visual inspection and where detailed inspection is important.

• Indirect Lighting: The illumination of the environment distributes 90% of the luminous flux to different surfaces and is reflected from these surfaces. In terms of efficiency, the reflecting surfaces should be painted in light colors.

• Color Temperature of Light: The choice of the color temperature of light has nothing to do with physical temperature. The concept of color temperature means the visible color of the emitted light. A cooler light color appearance is generally preferred in warm climates, while a warmer light is preferred in cold climates.

• Color rendering: Indicates how close the light source is to the true colors of the objects. The highest color rendering value (CRI) is 100. This value decreases as the light quality decreases. One of the most important parameters in the perception of colors is the perception of the eye. Colors evoke different physiological and psychological effects for each individual. According to the CRI, these effects can create positive or negative consequences. CRI offers the chance to organize an environment according to the light requirement. The structure of the object, light transmittance, light reflection, brightness, or opacity may cause different results in seeing the object.

• Daylight: Daylight has a variable phenomenon. It changes with time and spectral composition. Benefiting from daylight as much as possible will provide an advantage in terms of cost. In addition, the preference for daylight in workplaces is also effective in terms of employee health and safety.

2. Lighting standards ın light-sensitive areas

There are two basic criteria in the illumination of museums and exhibition spaces. The first is to ensure that the visitors perceive the exhibited works correctly, and the second is to minimize the distortions that may occur in the objects due to lighting. These criteria should be taken into account in the design of natural and artificial lighting systems (Özenç et. al., 2014; Cengiz and Cengiz, 2018).

The desired illuminance value on the exhibited objects varies according to the effects of the objects on the light. According to CIE-2001: Lighting of Indoor Workplaces, objects are grouped according to their sensitivity to light. While the recommended limit for materials with organic content is 50 lx, there is no mandatory limit value for the display of light-insensitive objects such as stone, glass, and metal. Since the correct perception of the exhibited works is directly related to the color of the light, care should be taken in choosing the lamps with a color rendering index (Ra) of 80 or above (CIE, Lighting of Indoor Workplaces).

• Objects insensitive to light: Stone, metal, ceramics, glass, gemstones, enamels, etc.

• Objects of low sensitivity: oil paint, glue paints, natural leather, wood, horn, bone, ivory, lacquers, some plastics

• Objects of medium sensitivity: vintage fabrics, watercolors, crayons, vintage carpets, prints and drawings, handwriting, miniatures, wallpapers, natural science examples

• Objects of high sensitivity: silk, some volatile dyes, newsprint

It should be ensured that the surfaces on which the paintings are hung should be illuminated as properly as possible and that the visitors can watch the works without glare. Lighting devices should be placed in such a way that they do not create reflections on the painting surfaces, and the frames used in the paintings should be chosen in such a way that they do not create shadows. In addition to general lighting, the position of the visitor should also be taken into account in determining the light direction, especially in the illumination of three-dimensional works. The light should

be directed in such a way that it does not create glare in the eyes of the visitor.

The colors, light reflectivity, and textures of the wall, floor, and ceiling surfaces are highly effective in the perception of the works. The use of matte surfaces gives positive results to prevent reflections on the floor and walls. Different materials are also affected by light differently. For example, fading is more common in watercolors than in oil paintings. Some colors may disappear completely, while others may remain in their original state, which may disrupt the color harmony in the picture. In oil paints, on the other hand, the thickness of the paint, the chemical structure of the paint, and its sensitivity to light can reduce deterioration. For this purpose, works should be illuminated by taking into account the light sensitivity of their materials. However, it is recommended that the collections, which are illuminated at the same levels, should be exhibited in volumes close to each other to enable the eye to adapt.

According to CIE-1986: Guide on Interior Lighting, the maximum allowable illuminance levels are specified depending on the materials of the works. Low sensitivity objects: 200 lux, Medium sensitivity objects: 50 lux, and High sensitivity objects: 50 lux are accepted as the limit values. Accordingly, according to CIE-157-2004: Control of Damage to Museum Objects by Optical Radiation standards, various limitations have been introduced in terms of preventing deterioration by considering the duration of illumination of light-sensitive objects together with the illuminance level. In this study, illumination was made according to the 50 lux illuminance condition specified by CIE for medium and high-sensitivity objects.

3. Lighting In Light-Sensitive Areas

Considering the psychological effect of lighting in public areas, the importance of artificial lighting is indisputable. Artificial lighting enriches the perception of space by providing a better perception of the details in the space. The circulation areas illuminated with artificial lighting in museums facilitate the change of visual focus and draw attention to the artifacts (Erkin and Onaygil, 2014; Cengiz et al., 2015; Erkin et. al., 2008).

It is possible to group the works exhibited in museums and exhibition halls into paintings and paintings, sculptures and reliefs, jewelry and showcases. The main problem encountered in painting and painting exhibitions is the brightness differences caused by the uneven vertical illumination level on the exhibition walls (Parlakyıldız, 2023; Cengiz, 2022). In the exhibition of paintings and paintings, the artificial lighting system should be designed in such a way that it does not cause reflections on the exhibited objects. Problems with reflection are often encountered in pictures under glass. Care should be taken so that the shadows are not disturbing in the lighting of the sculpture. For relief, the light should be directed strongly, as the three-dimensionality is less obvious. The correct choice of the direction of the light and the shadow are important in emphasizing the surface features of the exhibited objects and the three-dimensional effect of the sculptures (Özkanlı, 2022; Özkanlı, 2022). Showcase lighting can be done from inside or outside the showcase. The main problems in window lighting; The specular reflections on the glass surface are the shadows of the visitors or objects around the reflective surface on the showcase and the heat increase in the showcase caused by the lighting devices. Transparent barriers designed between the light source and the exhibited object prevent unwanted heat from damaging the object and protect the space from unnecessary heat increase. In cases where the showcases are illuminated from within the glass space, lighting devices are usually placed in the spaces left in some or all of their upper points (Cengiz, 2022). Attention should be paid to the direction of the light by hiding the light source from the audience. To maintain the

lighting devices mounted on the showcases, it should be aimed that the accessibility is easy and that the exhibited objects are not damaged during the repair or replacement. If the light source is positioned outside the showcase, the source should be above the front surface of the showcase, the light direction should be perpendicular to the ground plane, and the viewer's shadow should be prevented from falling on the work. The causes of specular reflections on horizontally or vertically designed glazed surfaces are luminous ceilings, luminous sections at the top of the walls, illuminated ceilings, or various devices placed in inappropriate places. For these reasons, it is necessary to increase the brightness of the exhibited objects as much as possible to prevent situations that cause discomfort and to keep the brightness of the surfaces that are thought to disturb the visitor as low as possible. Reflections can be reduced by the use of glasses with matt outer surfaces or coated with special films in the showcases (IESNA, 2000). The Turkish-Islamic Art Museum, where silk carpets with high sensitivity are exhibited, can be seen in Figure 2.

Figure 2. Turkish-Islamic Art Museum where silk carpets with high sensitivity are exhibited (URL-2)

4. Lighting design and implementation

One of the most important parameters in the perception of objects is the perception of the eye. Colors evoke different physiological and psychological effects for each individual. Accordingly, these effects can create positive or negative results. The structure of the objects, light transmittance, light reflection, brightness, or opacity make the object easier or harder to see. Therefore, the lighting design is the decisive parameter in this study.

The lighting quality should always provide adequate visual performance for the task involved. Average illuminance level, homogeneous distribution, glare control, and color rendering are the quality parameters taken into account in providing visual comfort. Inadequate lighting makes documents or computer screens difficult to see due to inappropriate lighting levels, glare, and unwanted shadows. Insufficient lighting prevents the correct perception of the environment, objects, and colors. Artificial lighting systems can be beneficial in environments such as museums where daylight cannot be utilized sufficiently. However, excessive lighting damages the works in exhibition areas such as museum environments. For this reason, the optimum light balance should be adjusted according to international lighting standards.

4.1. Illuminance level

The illuminance level, which is the ratio of the incident luminous flux per unit of time to the surface area, is obtained by dividing the luminous flux of the surface by that surface area. Its symbol is 'E' and its unit is lx. Mathematically, E (Illuminance Level) is called the ratio of Luminous Flux

to Area. While the intensity of light falling on a certain surface area does not change, the level of illuminance in that area does not change. "Lighting quality" changes. However, although the light intensity remains the same, the level of illumination depends on the change in distance. In general, when referring to measured and recommended illumination levels, reference is made to values reaching the horizontal working plane (Yavuz et al., 2019; Cengiz and Cengiz, 2018; Parlakyıldız et al., 2020). According to CIE criteria, an average of 50 lux condition was tried to be provided in the museum environment for medium and high sensitivity works. The ceiling height where the lamps are located is 6 m. For this reason, the distance between the surface to be illuminated and the lamp is included in the calculation as 6 m. Luminaires to be used in area lighting have been selected according to the lighting level, the brightness level of the area and walls, lighting homogeneity, and economic criteria. Calculations were determined according to the point illumination method. The lighting system for area-surface parameters is in a double-row suspension arrangement. The top view of the area where the Point Illumination Calculation is made is shown in Figure 3 (URL-3).

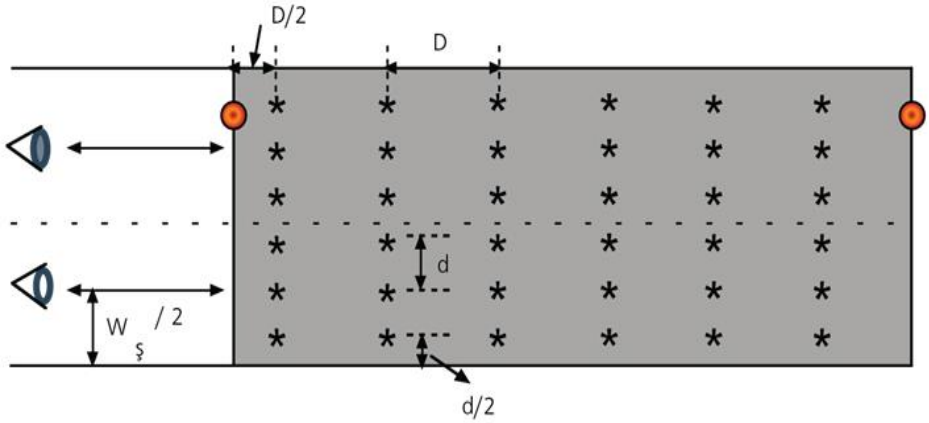

Figure 3. Top view of the area where Lighting Point Calculation is made

As lighting parameters, features such as distance between lamps, lamp height, lamp distance to the surface, IP protection class, pollution rate, cleaning time, and maintenance factor were selected. For the luminaire parameters, variables such as the angle of the luminaire relative to the surface, the power of the luminaire, its life, and the luminous flux were taken into account in the calculation. LED luminaires with a luminous flux value of 10500 lumens were used in the museum environment. The luminaire angles were chosen as 0, the floor reflectivity of 0.10, and the maintenance factor of 0.93 (for less polluted environments cleaned annually). A closed area with insufficient natural lighting is selected. The working area is 10.50 m wide and 63 m long. The area between the two luminaires where the point lighting calculation is made is divided into 90 points. The average illuminance level ($E_{average}$) for each rectangular area was calculated by dividing the 10.50 m * 63 m area into 90 equal parts of 2.10 m * 1.167 m dimensions. $E_{average}$ should provide 50 lux.

Table 1. Lighting parameters for the museum environment

Lighting parameters	
Height of lamp from ground (m)	6
Distance between luminaires (m)	21
Armature Angle (degree)	0°
Type of the Lamp	LED
Lighting Arrangement	Double row
Lamp luminous (flux)	10500
Area Length (m)	10.50
Area Width(m)	63
Ground reflectance factor	0.10
Maintenance Factor (once a year)	0.93
Height of lamp from ground (m)	6

In Table 1, the condition that the $E_{average}$ value is 50 lux and above for 90 points in the selected area for the lighting scenario has been checked. Illumination values of 90 points calculated for illumination in the museum environment are shown in Table 2.

Table 2. Illuminance values for 90 points calculated for direct lighting

Emin=17,63 Lux Emax=123,83 Lux Eaverage=49,94 Lux Uoa=0,36 Ula=0,14										
	1,050	**3,150**	**5,250**	**7,350**	**9,450**	**11,550**	**13,650**	**15,750**	**17,850**	**19,950**
0,583	38,766	30,593	23,754	18,799	17,626	17,628	18,805	23,765	30,609	38,792
1,750	49,595	41,865	31,024	25,228	27,352	27,354	25,234	31,035	41,881	49,621
2,917	67,785	55,924	41,552	38,190	42,145	42,147	38,196	41,563	55,941	67,812
4,083	100,708	86,964	59,396	55,984	57,911	57,913	55,990	59,406	86,980	100,734
5,250	123,802	108,550	68,589	61,878	61,926	61,928	61,884	68,600	108,566	123,828
6,417	100,708	86,964	59,396	55,984	57,911	57,913	55,990	59,406	86,980	100,734
7,583	67,785	55,924	41,552	38,190	42,145	42,147	38,196	41,563	55,941	67,812
8,750	49,595	41,865	31,024	25,228	27,352	27,354	25,234	31,035	41,881	49,621
9,917	38,766	30,593	23,754	18,799	17,626	17,628	18,805	23,765	30,609	38,792

In the calculation made, the condition of providing 50 lux illumination level according to the conditions specified in the CIE standards is provided in environments where there are light-sensitive materials/works, that is, in an exhibition area. $E_{average}$: Calculated as 49.94 Lux. In this way, a value of approximately 50 lux was reached, preventing light-induced damage to the silk carpets in the carpet museum.

5. Results

Lighting design should be handled with care so that the works exhibited in light-sensitive areas can be watched for generations without deterioration and various works of art are presented to the visitors. In this process, it is seen that each area lighting project requires a unique solution according to the international parameters specified in the CIE standards.

The selection and placement of lamps and devices should be carried out by the correct perception of the works, their protection, and energy conservation. Illumination levels must be within acceptable values for the preservation of exhibits.

The museums in Turkey should be designed in terms of lighting, and necessary studies should be carried out in terms of lighting design to ensure that the artifacts are perceived correctly by the visitors and preserved as much as possible, and transferred to the next generations.

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