



Achieving Optimal Lighting to Improve the Functional Performance of the Museum Using Computer Simulation

Case Study: Lattakia Museum in Syria

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Abstract

Is it possible to achieve optimal lighting in the museum space, which improves its functionality? And how is that done? This article discusses the previous question to achieve specific purposes: highlighting the importance of lighting in public buildings, especially in museums, and emphasizing the importance of using computer technology in the process of studying and proposing solutions that contribute to improving the performance of lighting in the museum (Lattakia museum in Syria as a case study). The study method is concerned with the use of environmental analysis software (ECOTECH Desktop RADIANCE) applied to the case study, which leads us to main results that can be summarized in: emphasizing the role of lighting in the process of optimal performance in the museum in the event that the lighting is natural, and choosing the appropriate lighting element in the event that the lighting is artificial, which later recommends the architects or designer the necessity of conducting research and design studies on natural and industrial lighting in the design stage to upgrade the museum to perform the optimal performance of the View exhibits process.

Keywords: Natural Lighting; Artificial Lighting; Museums; Lattakia Museum; environmental analysis software; ECOTECH; Desktop RADIANCE

1. Introduction

Lighting plays the most important role in the architectural space, as it is one of the most important design considerations, and it is supposed to be taken into account to achieve the best performance of the building. so Lighting is included in the basics of architectural work.

Lighting is used to determine the shape, colour, and texture of the spaces, but the external factors (such as climate) and the internal factors (the type or function of the space) make the study difficult for the designer because he needs to control both natural and artificial lighting, so the role of lighting has emerged as an important element for the study by the designer during the design process.

Museums are among the most affected types of buildings by lighting due to the diversity of their internal functions and their sensitivity to lighting

As its exhibits are of an archaeological nature, and the role of the computer has recently emerged in the study of lighting performance in museum buildings, whether it is in the design stage, or in the evaluation stage of an existing building.

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In this research, we will use two computer programs (ECOTECT - Desktop RADIANCE) to evaluate the lighting performance in Lattakia Museum and make special recommendations to achieve optimal performance in it.

2. Research Content

2.1. Research problem:

The research problem lies in the fact that the study of lighting was one of the secondary issues in the Syrian public buildings and museums in particular [1].

This is due to time periods, natural and design variables, or perhaps the function of the building changed during its life, and because museums are sensitive to light due to the archaeological holdings in them, in addition to the difficulty of coordination between natural and artificial lighting, which negatively affects the internal space of the museum.

2.2. Research importance:

The importance of the research lies in the study presented to achieve optimal lighting in the architectural space in order to improve the functional performance of the building and study Lattakia Museum as a case study by highlighting the importance of light and lighting in the architectural design of this museum, and the importance of natural lighting as an essential element that plays a positive role in museum buildings through The method of its employment and the method of inserting it into the space, as the research shows the importance of artificial lighting as an essential element or participant with natural lighting in completing the functional and formal element in the museum , The importance of the research also lies in highlighting the importance of the computer in the study of lighting and presenting a new concept for it ,and the adoption of Building Information Modelling (BIM) has increased significantly over that last few years [2] to improving the project's performance and efficiency [16] when the adoption level of BIM remains much lower than expected [4], Although the implementation of BIM were personal correlated issues such as resistance to change and lack of appropriate awareness of BIM [5], thus choosing the appropriate design solutions for Lattakia Museum, which is one of the most important museums in the Syrian Arab Republic. BIM also can be used at all stages of the projects, but it takes educational bodies time and effort to have qualified engineers that can implement new technologies [3].

2.3. research aims:

- Highlighting the importance of lighting in public buildings and museums in particular.
- Combine the importance of using computers in the process of studying lighting.
- Suggesting some solutions that contribute to improving the lighting performance in the Damascus National Museum.

2.4. light and its effect on human and architecture:

Light is the basic element to do the viewing process and it is [part of a wide spectrum of electromagnetic waves] [6].

[The electromagnetic spectrum includes gamma rays, x-rays, ultraviolet rays, visible spectrum, infrared rays, radar waves, FM waves, television and radio waves, power transmission waves] [6].

Light is considered the main element in the perception of space in architecture, especially in museum display spaces, as the perceptual process, especially visual perception, has an important impact on human behavior, because any visual perception of an element leads to giving a meaning, and after giving a person a meaning to the element that they see results in a specific behavior that expresses Thus, either it is a positive behavior that supports the environment, or a negative behavior that may affect the built environment, distorting and destroying it because it does not understand the elements in it, according to the figure 1.

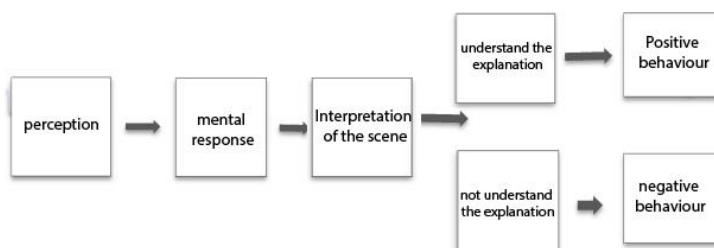


Figure 1: shows the effect of lighting perception on behaviour

2.5. Light attributes

Light has specific characteristics that affect and control human perception, and by controlling light it is possible to avoid, as far as possible, the occurrence of fatigue, which is the biggest negative reflection of poor lighting on humans, as the vision process in the case of works that need visual focus is different from the usual vision process, that is, The process that requires visual focus requires a muscular effort for the human eye, and the greater the details, the greater the muscular effort of the eye, and in the case of poor lighting, the process of adapting to focus becomes more difficult, whether the defect is in the amount of lighting or the types of devices, and that adaptation in changing circumstances is so great that Poor lighting conditions may not sometimes affect the viewer at the same moment or during work, but rather cause a feeling of fatigue after a long period as a result of the accumulation of stress. These symptoms are known as visual fatigue [7].

Light attributes are as follows

2.5.1. Light quantity

The amount of light is considered one of the important elements in the lighting process in order to reach a specific process and within special conditions to achieve a successful lighting performance [6].

The surrounding conditions or the environment are important to reach certain brightness levels in order to perform a good visual performance, as the visual performance lies in the perception of elements and details despite the change in the surrounding environment. For example, when the amount of natural lighting is good, the details of the displayed element can be perceived, but if it becomes This lighting is not sufficient and must be controlled. For example, in the case of museums, the change in lighting conditions throughout the day may affect the understanding of the details to be emphasized. For example, artificial lighting is activated at certain times of the day to support natural lighting, or the amount of natural lighting entering from windows may be controlled.



Figure 2: the lighting of the display space itself in different conditions, where the lighting was adjusted in the case on the right (clearly defined painting), and was not set on the left (vaguely defined painting) as it was at a level of lighting higher than necessary.

2.5.2. Light quality

[The lighting may be uniform and give light and less clear shadows, and the light in this case is called diffused light] [8].

[And the lighting may be directed at a specific element and give multiple shades, and the light in this case is called direct light] [8].

Comparison between direct and diffused light

Table 1. comparing between direct light and diffused light

Direct light	Diffused light
<ul style="list-style-type: none"> -The light source in this case is point. - We say in the case of natural or daytime lighting that the sun is the direct source of light. - We say in the case of artificial lighting at night that a point artificial lighting element suffices as a direct lighting source. - Natural lighting can be supported by artificial lighting as a direct light source during the day. - Direct light is characterized by producing shadows for objects and reflections on bright objects. -Direct light does not only produce shadows and reflections, but also helps designers to choose the angles and directions of the light rays as it is able to control them. 	<ul style="list-style-type: none"> -The light source in this case is a surface. -We say in the case of natural or daytime lighting that the sky is the source of diffused light. - In the case of artificial lighting at night, we say that an artificially luminous ceiling, or perhaps light reflected from a luminous ceiling or wall, one of which is appropriate. -Natural lighting can be supported by artificial lighting as a diffused light source during the day. - Diffused light is characterized as uniform and dim, giving shadows and reflections to visible objects. -The percentage of diffused light decreases when the walls receive a little light or when it is absorbed on the surface in a large way with a low reflection coefficient for the surroundings or the environment and it can be used for dramatic effects with intense lighting.

In the following images, we notice how lighting conditions affect perception, for their impact on understanding details and shadows, for example.

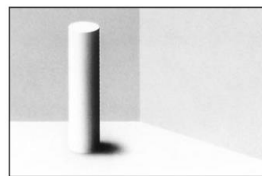


Figure 3: In the case of uniform lighting with diffused light, the shadows are lighter and less clear.

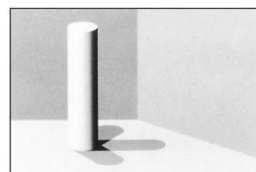


Figure 4: In the case of directed lighting, with directed light, the objects within the space will receive multiple shadows.

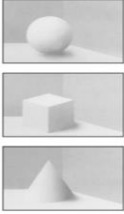
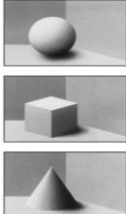
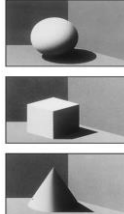
		
<p>Diffused lighting produces negligible shadows, and shapes and surface textures are poorly distinguished</p>	<p>Lighting that includes both diffused and direct lighting produces soft shadows. Shapes and textures can be clearly distinguished, and there are no confusing shadows.</p>	<p>Directed light produces clear shadows and strong shaping effects. Shapes and surface textures are emphasized, while details can be hidden by shadows.</p>

Figure 5: Perception of three-dimensional shapes under different lighting conditions.

2.6. Light attributes

In the following, we find the most important conditions that can be controlled during the study of lighting and may prevent optimal performance and thus affect the process of vision and perception of space:

2.6.1. luster

[luster occurs when light falls on the shiny surface of surfaces, and luster is considered one of the basic features of directed light and its effect is negative on smooth surfaces] where luster depends on the intensity of light or on light as an auxiliary element, but it does not depend on it mainly, as the greatest dependence is on reflection or refraction, for example: [A low-voltage halogen lamp, which is a lamp with very compact light, creates reflections with larger surfaces than lamps with less compressed light, and the luster is considered confusing when it causes glare] [8].

2.6.2. glow

[It is the decrease in visual performance, and the occurrence of self-disorder that individuals feel through excessive levels of lighting or strict discrepancies in the level of lighting within the field of vision, and when the glare is limited and acceptable, the lighting is good]

When glare occurs, visual performance decreases and a self-disorder occurs in the viewer due to more lighting levels than usual, or as a result of a discrepancy or difference in the level of lighting within the field of vision [8].

2.7. Natural lighting

Natural lighting plays an important and essential role in architecture and plays the biggest role in defining the architectural dimensions and creating healthy and suitable spaces for human life and the continuity of its activities in the fullest and safe way.

Natural lighting is relied upon in most architectural buildings more than artificial lighting because of its benefits, in addition to being renewable energy and achieving the principle of sustainability [6].

Natural lighting is considered the main element of lighting in architectural spaces, but its use may be reduced if it cannot be controlled or if the spaces are very sensitive to ultraviolet or infrared radiation, as in hospitals and also museums that are at the case study in the research.

Museums display elements that are sensitive to light, and natural lighting is usually used in museums in the spaces that do not contain exhibits, such as corridors and the administrative section, for example. If they are used in exhibition spaces, they are controlled so that they do not directly affect the exhibits.

Natural lighting provides a direct connection with the external environment and is more than just adding large windows or skylights, but is a wise combination of design strategies, such as heat gain, glare, diversity in light availability, direct light penetration into the building, shadow formation methods, materials used and light reflection.

the art and science of natural lighting is not so much how to secure enough lighting as it is how to work without its potential undesirable effects [6].

Natural lighting can be controlled by methods, including the use of breakers that can be added to an existing building, or the use of overhead lighting, or controlling the depth of internal spaces, in the design or interior modification process.

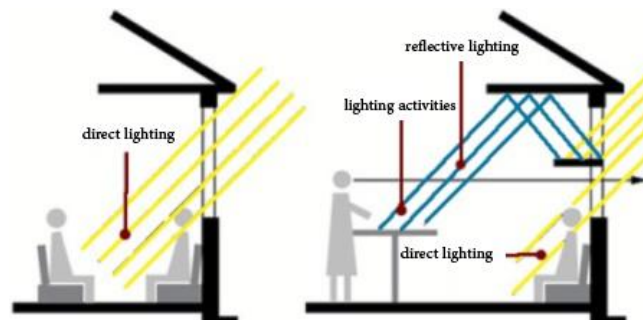


Figure 6: distribution of natural lighting using sun breaker.

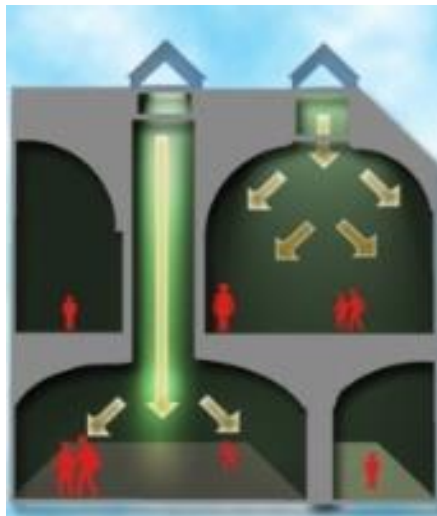


Figure 7: Natural lighting distribution using overhead lighting.

2.8. Artificial lighting

It is the lighting that depends on an unnatural artificial source.

The task of artificial lighting, in addition to ensuring viewing and natural viewing conditions when performing various works and activities, is to take into account the aesthetic aspect [5] as long as light is an important element in the forms of art through which it is possible to show architecture and emphasize its elements, organize the space, create a specific artistic image and influence emotions human impressions.

This lighting may be general, local, constructive, or decorative [10].

There are many types of lighting devices used, and we mention the most important lighting devices used in museum spaces, which are as in the following table:

Table 2: Artificial lighting devices.

used lighting system	Lighting type	The best light sources used
Illuminated ceiling lights	directed and spread	fluorescent
indirect lamps	directed and spread	fluorescent
cove lighting	spread	fluorescent
*Wall washer	directed and spread	fluorescent compact fluorescent High voltage halogen
Spots light	directed and spread	High voltage halogen
LED	spread	Special LED lights

* Wall washers: linear lighting sources that provide a large lighting area. Therefore, it is said that this type of lighting system adopts the principle of washing walls with light, which means providing a bright surface on a wall for display [11].

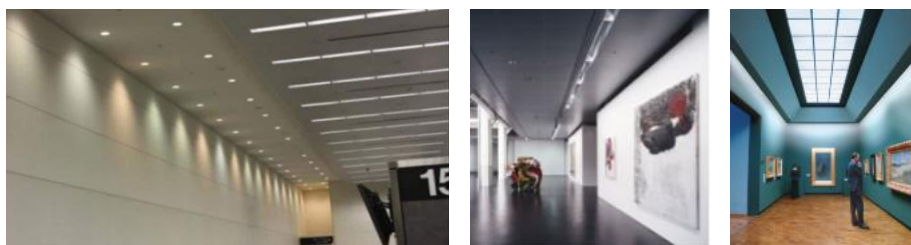


Figure 8: on the right, lighting using illuminated ceilings.

Figure 9: In the center, the luminance using wall washers.

Figure 10: on the left, lighting using LEDs and spotlights together.

2.9. Lighting and achieving optimal performance in the architectural space

The optimal functional performance of the interior space is not achieved by using lighting automatically, but after a deep study that may direct the architect to use one of the two natural or artificial lightings, or to share between the two natural and artificial lightings, and to integrate and control them as well.

One of the methods of studying lighting during design or after design of a building to be evaluated is the use of computer technologies that may play a major role in this field, especially in the field of controlling lighting performance.

2.10. The role of computer technologies in the study of lighting:

Since its existence, the computer has been considered a revolution in the world of technology, and its importance has emerged in all fields of life and the development of its use with time, especially in the field of architecture, where it was used in building modeling to obtain complete drawings of the modeled building such as plans, elevations, sections, etc., and was used to calculate quantities, specifications and studies Executive, and its role has recently emerged in recent years in the environmental study of the building designed to evaluate it or suggest modifications that lead to a better performance, whether in the field of ventilation, lighting, sound, etc., as the research here deals with the importance of the computer in studying the lighting on the museum building and its reflection on The functionality of the building.

The computer also studies the cases that were previously mentioned in the research, such as luster, glow, and color, and makes the building under experimentation on the computer, where these cases can be controlled to reach an optimal lighting in the space.

There are many computer programs that study lighting in buildings, including the ECOTECT program and the DESKTOP RADIANCE LIGHTING program, which are the two programs that will be used in this study.

2.10.1. Introducing the programs used in the research

2.10.1.1. Autodesk ECOTECH Software

It is an application of BIM technology, when the Syrian AEC industry is witnessing the transformation from CAD to BIM so it must be encouraged by the government and other related firms and individual expertise to spread it as much as possible in order to keep up with the ever-evolving world of technology [12]

ECOTECH is an analysis software program for the sustainable design process and provides many simulations and energy analyzes that increase the efficiency of existing or new buildings.

It performs an energy analysis for the entire building, as well as an analysis of consumption and lighting.

This program is used in the research to study the influence of natural lighting through the space and to determine the main points where direct light falls on the areas of the exhibits. This analysis is carried out to determine the approximate number of hours in which the building exhibits exceed the recommended annual lighting hours, which leads to possible damage due to light in addition to the elements of artificial lighting [13].

2.10.1.2. desktop RADIANCE Software

It is a set of tools that simulate lighting and provide many simulations and energy analyzes that increase the efficiency of existing or new buildings.

This program is used to simulate the quality and quantity of light in the building, where the lighting levels are calculated at basic reference points in the museum, and then verify the percentage of hours during which these points are above the recommended lighting levels, and many electronic pictures are taken using the computer [13].

Table 3: Ecotech and Desktop Radiance programs software inputs and outputs.

Software program name	inputs	outputs
Autodesk ECOTECH Software	<ul style="list-style-type: none"> - three-dimensional model of the building in which lighting is to be studied, and it is modeled on one of the three-dimensional software programs, such as 3DS MAX, where it is included in the program as a first step, and the building can also be modeled on the ECOTECH program itself. - Information about the project, which is entered using the Windows method, which is the information of the project site, which is automatically attached to the climate in terms of temperature, humidity, winds, etc., in order to link the site to satellites. All this data can be entered manually in order to design an unrealistic virtual site. -Determining the building materials used in each component of the building, because the material has an important role in the process of studying lighting, as some materials are reflective, some absorb light, and some materials cause glow and luster and need a different treatment than if they do not cause 	<ul style="list-style-type: none"> -Determine the main points where direct light falls on the spaces whose illumination is to be studied. -The timing of the highest penetration of light into space by day, hour and minute. - The approximate number of hours in which the studied spaces exceed the recommended annual lighting hours. - It combined with the effect of artificial lighting devices as well.

	<p>glow or luster.</p> <p>-The used artificial lighting devices are added from the ECOTECT program library and placed in appropriate places that simulate reality.</p>	
desktop RADIANCE Software	<p>- It is similar to the ECOTECT program in terms of the same inputs, but the difference lies in the input method, as RADIANCE adopts a method of data entry in a way that is closer to the programming system, numbers and symbols, unlike ECOTECT, which relies on windows and drop-down lists.</p> <p>- RADIANCE is more difficult than ECOTECT to make inputs.</p> <p>- A file attached to the inputs from the ECOTECT program can be inserted into RADIANCE, as only the process of analysis and access to the results takes place in the RADIANCE program.</p>	<p>- RADIANCE gives results similar to the ECOTECT program and is usually used to confirm results or to support results.</p> <p>-Total annual lighting hours.</p> <p>-The average amount of illumination at a specific reference point in a space or in a space as a whole.</p>

We turn to the local study case, where the two programs were used together:

2.11. Lattakia Museum:

The research methodology was followed in:

- 1 - Introducing the museum.
- 2 - Study the variables affecting the study.
- 3 - Analysis using the computer.

2.11.1. Introduction to the museum

The museum is located in the western city center in front of the entrance to the commercial port. It is separated from the sea by a public garden called Al-Manshia. It is bordered to the north by Adnan Al-Maliki Street, to the west by Al-Andalus Street, to the east by residential buildings, and to the south by Al-Quds Street [14].





Figure 11: the location of Lattakia Museum in relation to the city of Lattakia on the map.

The main function of the building was as a “khan-hotel” in the Ottoman era, and as a residence for the High Commissioner during the French occupation, dating back to the end of the seventeenth century AD. Then the building was bought by Ibrahim Nasri, and in 1981 its ownership was transferred to the General Directorate of Antiquities and Museums, and restoration work began in the historical building and the establishment of the museum until the official opening took place in 1986. The museum currently occupies the ground floor of the building, while the first floor includes the first is the offices of the Department of Antiquities [14].

The exhibits were not generally exposed to sunlight, which preserved their quality.

As for the existing display cabinets, they are not good at all, and are not hermetically sealed, and the technical equipment is not well available (ventilation - lighting).

The building is historical and old, and the conditions for museum and scientific display are not available in the building, such as lighting, ventilation, temperature, and appropriate humidity, and the building’s stone is sandy in influence that does not suit the use of the building as a museum. It is suitable for museum display.

The museum is built of intrusive sandstone in light tones of gray and brown, with a traditional construction style [14].

As for the industrial lighting devices, there are overhead spots, especially in the cabinets, in addition to lanterns in the corridors [14].



Figure 12: The Hall of Ancient Antiquities - Ibn Hani' - in Lattakia Museum.

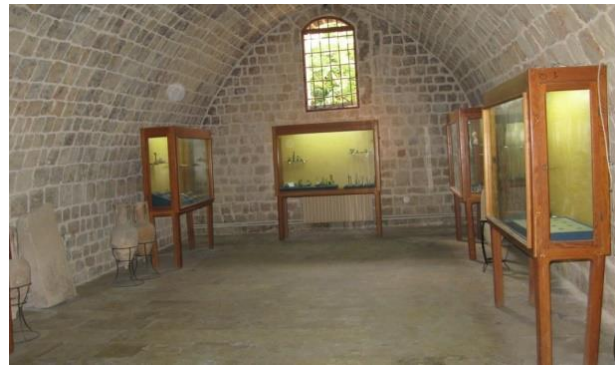


Figure 13: Classical Antiquities Hall in Lattakia Museum.

2.11.2. The spaces to be studied in the museum

The ground floor is the floor to be studied because it is the floor designated for Exhibits

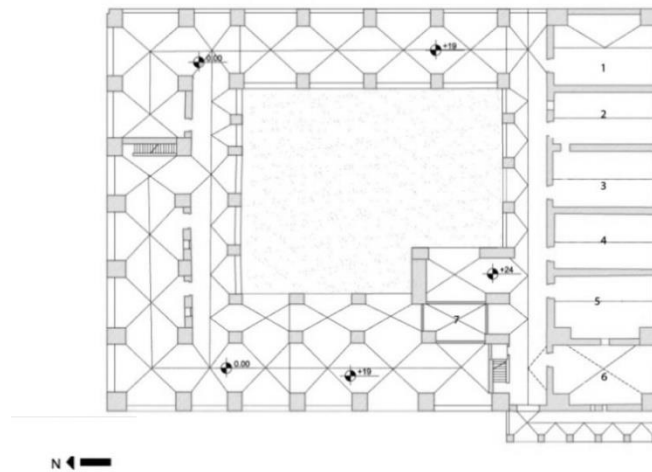


Figure 14: plan of the ground floor of latakia Museum.

Table 4: table of Functions spaces of the ground floor of latakia Museum.

table of Functions spaces			
number	space Function	number	space Function
1	Main store	5	Ancient antiquities exhibition hall (Ibn Hani)
2	Islamic antiquities exhibition hall	6	Reading space
3	Classic antiquities exhibition hall	7	library
4	Antiquities exhibition (Shamra)		

2.11.3. Study the variables affecting the study:

2.11.3.1. Openings study:

The museum elevations and openings were studied after being drawn in terms of shape and placement.

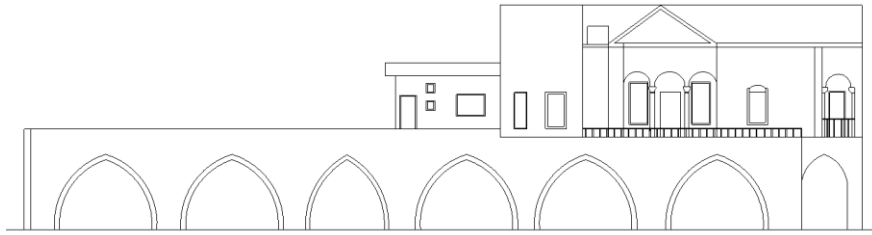


Figure 15: the northern elevation of Lattakia Museum.

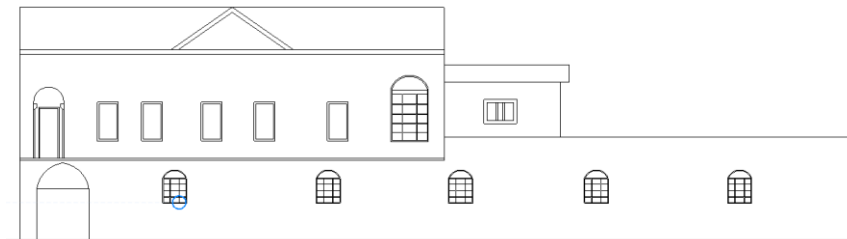


Figure 16: the southern elevation of Lattakia Museum.

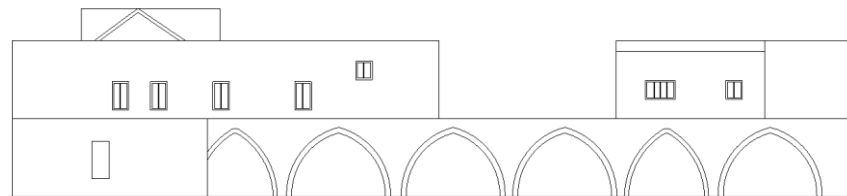


Figure 17: the eastern elevation of Lattakia Museum.

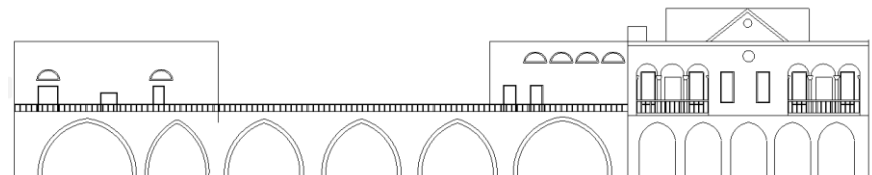


Figure 18: the western elevation of Lattakia Museum.

We notice that the elevations of Lattakia Museum contain the upper openings, which are small in relation to the height.

It can be seen the arcades on the elevations

2.11.3.2. Entry of natural lighting through openings:

Entry of natural lighting through openings:

After studying the openings, the museum was monitored between morning and afternoon at three o'clock in the afternoon due to the gradual decline of sunlight from the sunrise to sunset phase and because the museum was closed after this time at four o'clock.

The monitoring was carried out on a sunny summer day and a cloudy, not clear sky, in order to avoid strong sunlight, because the research studies lighting, not radiation.

From that, we notice the most illuminated places throughout the day as the lighting levels in the spaces create a state of confusing glow, and the museum exhibits do not suffer from luster because most of the exhibits are made of non-reflective materials.

The above information was collected from the museum staff, in addition to the frequent visits to the museum, and careful observation, and to prove this scientifically, it was later confirmed by computer analysis of the museum's lighting.

Openings are considered among the important elements for studying the natural light transmittance, so they are computer modeled as program inputs.

2.11.3.3. Used Artificial lighting devices:

Artificial lighting devices differ according to their type and their placement in the museum. This has been modeled on the computer as inputs, to know its effect on the lighting performance. They are upper lights, especially in the cupboards, in addition to lanterns in the corridors [14].

Table 5: the variables affecting the study in Lattakia Museum.

Study the variables affecting the study		
Openings study	Entry of natural lighting through openings	Used Artificial lighting devices
<p>- the southern elevation contains small openings, at the rate of one window for each hall, which are upper openings, as for the ground floor.</p> <p>the first floor, or administrative floor contains windows are similar to the windows of the ground floor, but lower.</p> <p>-The opening in the eastern elevation is small openings.</p> <p>As for the ground floor, its eastern elevation is roofed with arcades, except for the warehouse, in which a longitudinal window opens. As the corridors block the sun's rays.</p> <p>-As for the northern and western elevations, which is the entrance elevation, they are covered with arcades on the ground floor as well, with arcades also on the first floor.</p>	<p>Sunlight enters the ground floor in the morning, as the eastern sun does not reach the halls well because there are no exhibition halls on the eastern elevation, as the warehouse is located on the eastern façade as in the first-floor location.</p> <p>In the afternoon, sunlight penetrates the floors and the inner wall of the exhibition halls.</p> <p>As for the first floor, the upper limit of sunlight penetration occurs on the walls of the administrative spaces, because the depth of the void is small, so the sun reaches it more.</p>	<p>They are upper lights, especially in the cupboards, in addition to lanterns in the corridors.</p>

2.11.4. Analytics using the computer:

After modeling the museum as three dimensions, the analysis process takes place, where the program was supported by museum information such as the geographical location, which in turn gives the climate, and the mass was modeled with the real materials used in building and cladding materials, and modeling both opening artificial lighting devices.

2.11.4.1. Analysis using ECOTECH program:

The following has been reached regarding the entry of sunlight, taking into account the artificial lighting devices in the modeling:

Sunlight enters the ground floor in the morning between 8:00 and 9:30 am, as the eastern sun does not reach the halls well because there are no exhibition halls on the eastern elevation, as the warehouse is located on the eastern elevation, as in the plan of the first floor [10].

in the noon times between 1:30 and 3:00, sunlight penetrates to the floors and the inner wall of the exhibition halls.

for the first floor, the upper limit of the penetration of sunlight occurs on the walls of the administrative spaces, because the depth of the void is less, so the sun reaches it more, but since the research study targets exhibition halls, the wall of the exhibition halls corresponding to the windows will be chosen [15].

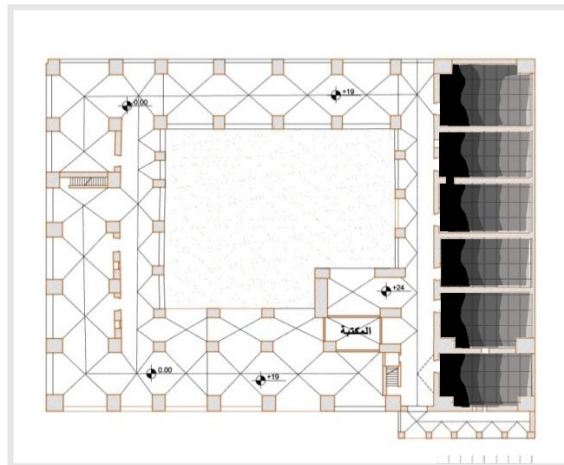


Figure 19: the sunlight transmittance in the floor that is most exposed to light in Lattakia Museum, which is the ground floor in the morning, as the shades of gray represent the gradient in the level of illumination, and the darker color symbolizes the lowest level of illumination.

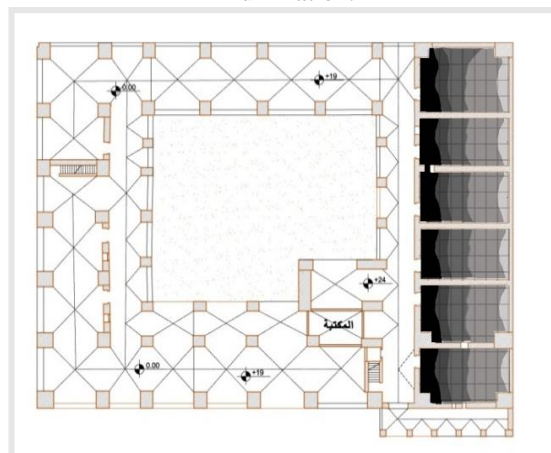


Figure 20: the sunlight transmittance in the floor that is most exposed to light in Lattakia Museum, which is the ground floor at noon, as the shades of gray represent the gradation in the level of illumination, and the darker color symbolizes the lowest level of illumination [15].

The interior wall of the halls opposite from the outside, with a gallery reaching the entrances of the halls, was chosen as the most critical wall in Lattakia Museum because of the hours of direct sun during the year, and the importance of studying it as a wall for exhibition halls [15].

June 21st will be adopted as a day for studying sunlight, as it is the day of the summer solstice in the northern hemisphere, where Syria is located, as it is one of the inputs of the ECOTECH program software, in addition to the region and the time 1:00 as the average time between sunrise and sunset [15].

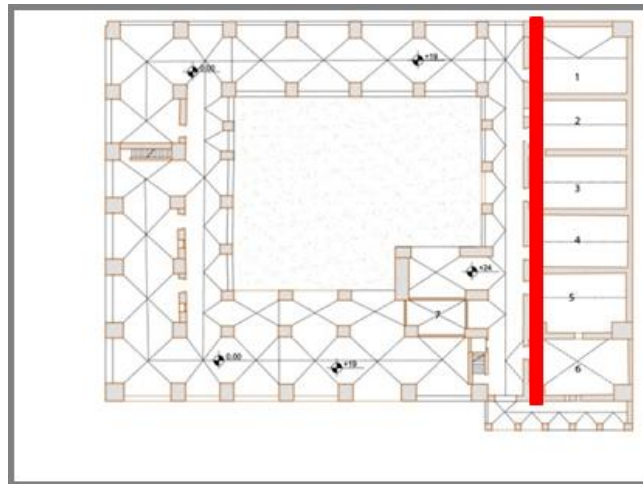


Figure 21: plan showing the wall most affected by natural lighting (sunlight) in Lattakia Museum, as a conclusion from the observation during the visit and from the analysis of the ECOTECT program software, because it is a reference wall on which will be studied in Desktop RADIANCE program software.



Figure 22: the effect of natural lighting (sunlight) from the southern elevation on the critical wall, which is the interior wall of the exhibition halls facing the windows in Lattakia Museum.

2.11.4.2. Analysis using Desktop Radiance:

The luminance level was calculated at the main reference point of the museum, using desktop radiance, which was simulated for all hours of daylight on a typical day (21) of each month for a full year [16].

The total lighting hours in the year reached 816000 lux-hr/year without counting the artificial lighting devices, and 817200 lux hr/year if the artificial lighting devices were counted; As this level in both cases is approximately 1.5 of the maximum recommended lighting hours, which is 480000 lux-hr/year for exhibits of medium sensitivity to light according to IES* standards [16].

*IES: Illuminating Engineering Society: It is a standards development organization accredited under the procedures of the US National Institute.

The highest values of illumination occurred during the noon hours during the year, with the highest value on August 21 at twelve o'clock in the afternoon, where the average amount of illumination was 215 lux without considering the artificial lighting devices and with it also with small differences, which is higher than the upper limit of the recommended average amount of illumination with which is 200lux for exhibits of

medium sensitivity to light [16].

The level of illumination during daylight hours in the Lattakia Museum is higher than 200lux in more than 40% of the year [16].

the highest values of the amount of luminance in the year in the Lattakia Museum occurred on the 21st of August at twelve o'clock in the afternoon [16].

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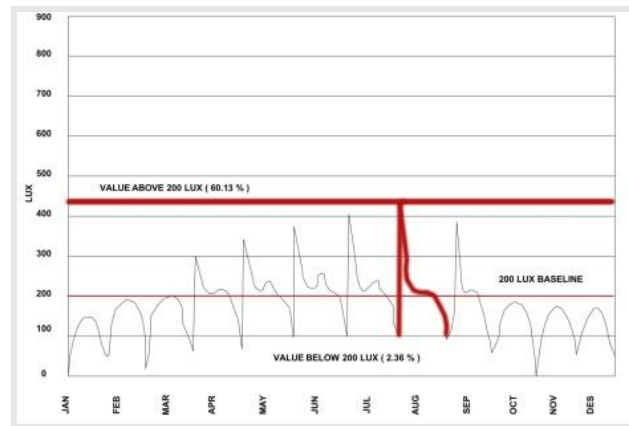



Figure 23: the highest values of the amount of luminance in the year in the Lattakia Museum occurred on the 21st of August, as the X axis represents the months of the year, and the Y axis is the level of the amount of luminance in LUX, from the RADIANCE program software.

The above simulation process on the two programs software can be summarized in the following table:

Table 6: The results of the simulation process on the two programs software used in Lattakia Museum.

The highest transmittance time for natural illumination	The place most affected by natural lighting at highest time	The level of illumination in the place most affected by natural illumination at highest time without regard to artificial lighting	The same lighting level if artificial lighting is considered (to see how it affects)
In the morning between 8:00 and 9:30, and in the afternoon between 1:30 and 3:00	The morning sun does not reach the halls well, because there are no exhibition halls on the eastern elevation, as the warehouse is located on the eastern elevation as in the first-floor plan. In the afternoon, sunlight penetrates the floors and the inner wall of the exhibition halls.	816,000 lux-hr/year	817200 lux-hr/year the lighting has a small negative effect.
Average annual amount of lighting	Compare the result with the IES standard	Timing of the highest values for the amount of luminance	optimal performance ratio

lux 215	<p>The illumination level is approximately 1.5 of the recommended maxima, which is 480,000 lux-hr/year for medium-sensitive exhibits.</p> <p>The average amount of illumination was higher than the upper limit of the recommended illumination level, which is 200 lux for exhibits with medium sensitivity to light.</p>	<p>The highest value is on August 21 at twelve o'clock in the afternoon.</p>	<p>Lattakia Museum did not achieve optimal performance in the display by using lighting by more than 40% of the days of the year, so it achieved 60% of the days of the year.</p> <p>Light gray represents optimal lighting performance.</p> 
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3. Results and Recommendations

3.1. Results

- Emphasizing the importance of museums as public buildings in which lighting plays an important role and in their functional performance over the course of their life as important and sensitive buildings for lighting and for as long as possible.
- The need to control natural lighting in museums because it is a double-edged sword, as it carries elements that affect the exhibits negatively, such as ultraviolet rays. Therefore, natural lighting is very important, but it must be used with caution in this type of important buildings.
- The need to choose the appropriate Artificial lighting element for the exhibits in the museum like LED lighting devices as a good example.
- The importance of computer technology in studying the lighting of an existing building in order to assess the state of lighting performance in order to develop better design solutions.
- The importance of computer technology lies in the study of lighting, adding a new concept to it, and thus choosing appropriate design solutions for the study case in Lattakia Museum, which is one of the most important museums in the Syrian Arab Republic.
- In view of the graphs of the daily illumination levels of the solstices and equinoxes in Lattakia museums, we notice a gradual decrease in the graph from the day of the summer solstice to the winter solstice.
- Despite the current situation of Lattakia Museum (sandstone as a building material - humid climate - poor technical services...), it is good at lighting, due to several reasons, including the size of small openings and the main dependence on artificial lighting.
- Lattakia Museum achieved 60% of the optimal lighting performance throughout the year, which is a good percentage for a building of this important nature.

3.2. Recommendations

- The need to conduct research and design studies on the subject of lighting, both natural and artificial, at the design stage and drawing up plans, which aims to upgrade the museum buildings to carry out their function in the fullest way, and to reach an optimal performance for the display process in them, as well as the ability to know the appropriate opening method.
- Control the entry of natural lighting by adding external shading elements to the windows to reduce the entry of light and heat, and when possible, the presence of trees and vegetation areas to filter the light and provide shading.
- Using glass with low UV rays and choosing coloured and dark ones to reduce lighting levels.

- If it is not possible to reduce lighting levels to 200LUX in the museum in some spaces, it is preferable to use spaces to display materials that are less sensitive to light (such as iron, stone, glass and ceramics).
- Using the active window system where the transparency can be controlled and set from 1% to 70% depending on the external conditions.
- The need to redistribute the exhibits within the museum, depending on the study of lighting.
- The need to choose appropriate artificial lighting devices, given that there will be a great deal of reliance on artificial lighting, as it is preferable to replace the lighting devices used in the Lattakia Museum with other types such as spotlights, and LEDs above the exhibits and sculptures, and the use of wall washers in places where the paintings (mosaic) are placed on the walls

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