



ROOF DAYLIGHTING FOR PRESERVING ARTWORKS WHILE ENHANCING VISITOR EXPERIENCE IN LONDON

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Abstract: Museums play a crucial role in preserving and displaying cultural artefacts. Museums consume a huge amount of energy and typically operate on a 10:00 to 17:00 hour cycle. Hence, incorporating carbon and cost-free daylight is imperative for creating a low energy museum. However, the idea of lighting a museum with daylight resonates as a complex concept. The tangible complexity of the research is undertaken with three distinct and applicable case studies based in London to help understand the use of daylight to its maximum potential. Useful Daylight Illuminance (UDI) tests are carried out for the entire year, but with the help of a typical sunny summer day, the study evaluates the extremities of light in a day and the impact of roof daylighting on visual comfort. It brings along the intangible complexities in a space which includes the user experience, and perception, investigated through designed questionnaires, and observations at site visits. The research concludes the implementation of an adaptable hybrid roof daylighting strategy as pragmatic for preserving artworks while enhancing visitor experience.

Keywords: Daylight, Museums, useful daylight illuminance

1. Introduction

Museums are generally known as traditional places where artefacts are stored and displayed for the purpose of entertainment, enlightenment, recreational, cultural and educational advancement purposes (Aderonmu, 2019). Museums have a responsibility to care for their artefacts. Museums have to pass them on to future generations in good condition (Vane, 2021). Hence, they play a crucial role in preserving and displaying cultural artefacts, and lighting plays a significant role in the overall ambiance and perception of exhibits. Lighting is a critical component in a museum environment because it enables visitors to see objects, experience new sights and react to the surrounding environment. However, daylight can not be incorporated into every space of a museum.

2. Precedents

There are multiple spaces in a museum that could be looked at. For the case of understanding daylight and incorporating it in the most effective way it is vital to select the right space to study and test.

2.1 Selection of Space

The daylighting strategies classified according to (Ander, 2003) are mainly divided into two ways of lighting, side-lighting and top-lighting. Wall lights are generally used more in passage or corridors. If used in the display area it would take up valuable exhibit space and create uneven distribution of light. The use of clerestory windows could help in reducing glare as they are placed above the eye level. While top lighting also referred to as roof light could

provide more homogeneous even light throughout the space. Hence, the study focuses on roof lighting.

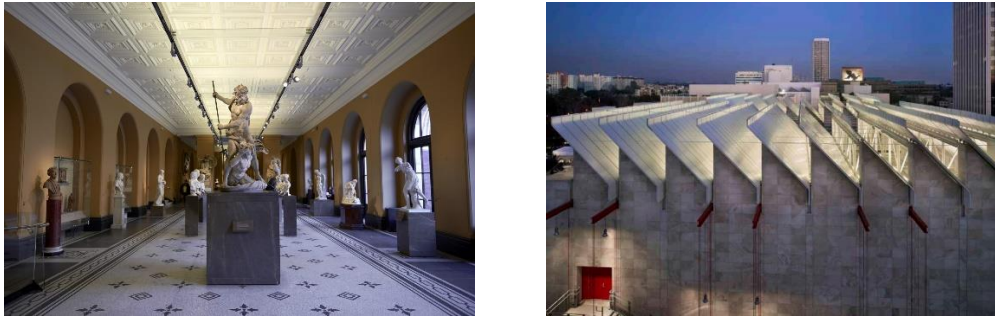


Figure 1. Wall light and Roof light in sculpture spaces, Victoria and Albert Museum, London & LACMA museum, Los Angeles

The painting spaces are filled with sensitive collections that could not be exposed to more than 50 lux as per CIBSE guidelines (SLL code of lighting). Hence, daylight is completely shut most of the time in painting spaces in galleries and museums. While sculpture spaces are also well workable within the benchmarks, as their exposure limits are more than paintings, they are selected for the study.



Figure 2. Painting display space and sculpture space in Kelvingrove museum, Glasgow, UK

A museum is comprised of various spaces. The spaces for casted sculptures and actual sculptures are kept in different areas with different light quality as per their requirements as shown in the ground floor plan of V&A museum below. Hence, actual sculpture spaces become critical in understanding the impact of light inside it.

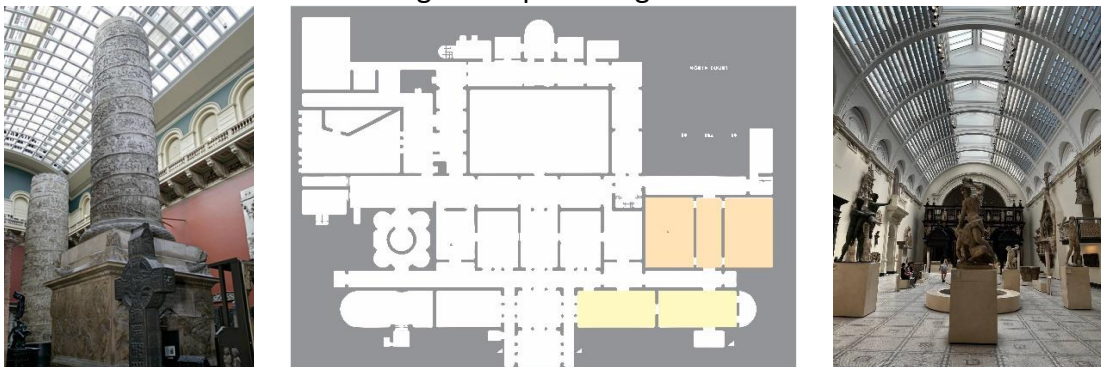


Figure 3. Casted sculpture space (orange) and real sculpture space (yellow) of Victoria and Albert Museum, London

A space that meets all the above criteria is selected for the study.

2.2 Selection of Roof

The sort of daylight openings utilized in galleries has a significant impact on how natural light is distributed throughout the space and on the sense of connection to the outside. Top-lighting is recommended to produce ambient and uniform illumination while also reducing the risk of glare. Ceiling apertures allow for openings without interfering with the space's organizational scheme, and they leave the entire wall surface available for exhibition. Skylights, overall daylight roofs, atriums and light wells are all examples of top-lighting apertures (Chidi, 2022). As shown in the figure below, there are three types of common and applicable roofs in London are adapted reused in museum buildings. For understanding these three roof types a case study is selected to suit each. For skylight, Victoria and Albert Museum is selected, Natural history museum is selected for monitor shaped roof and Newport Street gallery for saw tooth shaped roof type. All of them are located in London which helps in providing a basis for comparison.

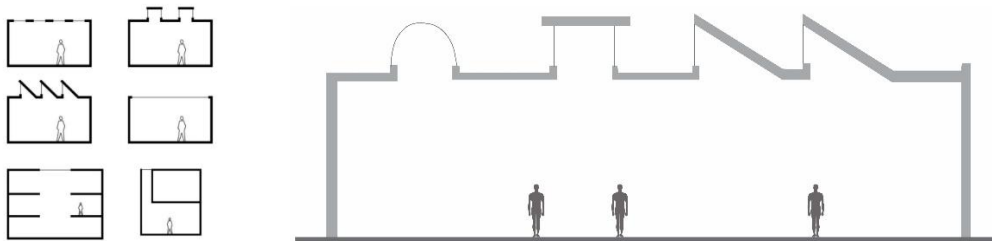


Figure 4. Different types of roofs, from left to right, Skylight, Monitor and Saw tooth shaped roof types

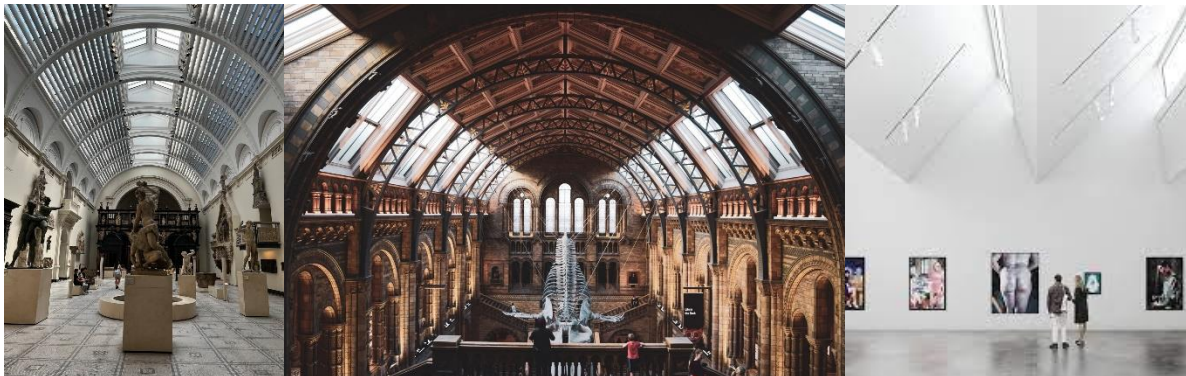


Figure 5. Victoria & Albert Museum, Natural history museum, Newport Street gallery (from left to right)

3. Fieldwork to calibrate daylight measurements

The intangible queries associated with daylight are addressed with a designed questionnaire about experience, satisfaction and perception of daylight by visitors and staff. It's accompanied with daylight spot measurements and developing an understanding of the multifaceted parameters of visual comfort.

3.1 Daylight Spot Measurements

The sculpture space in the V&A museum is divided into twelve equal parts. The center of each spot is taken to carry out spot measurements for daylight analysis. A lux meter is used to carry out the measurements on a typical sunny day in London. The summer lux helps in developing the understanding of the amount of illuminance allowed or accepted by one of the key museums in London. The interesting part is the large amount of difference between these two measurements. For e.g., at 11:30 the illuminance at top left and right spots is 6280

and 1420 lux respectively. The distance between both the spots is less than 10 meters while the difference between lux levels is drastically high. Henceforth, the impact of direct and diffuse light in a museum space is established.

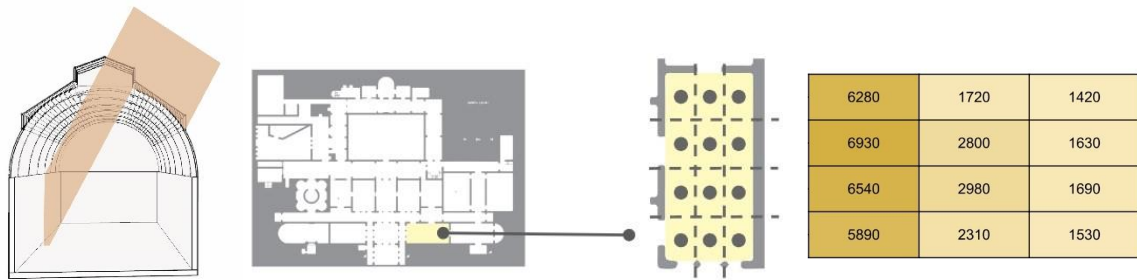


Figure 6. Summer solstice, Ground floor plan of V&A museum, 12 spot measurements marked in the space, 11:30 am spot measurement in marked space of V&A museum

4. Analytical work comparing the three selected roof types

Utilizing case studies with observational fieldwork forms the fundamental framework for developing a model to facilitate analytical work. The study encompasses the evaluation of three distinct roof types: skylight, monitor, and sawtooth to critically comprehend the illumination levels. To ensure a meaningful comparative analysis among these roof types, certain parameters are held constant while others are varied. Specifically, the dimensions of width and length for the space remain uniform across all three cases, introducing variation exclusively in terms of the space's height and roof profile. This deliberate manipulation of height and roof profile and precise model making aims to shed light on how variations impact the illumination levels within sculpture spaces, ultimately yielding valuable design recommendations tailored to London's climate.

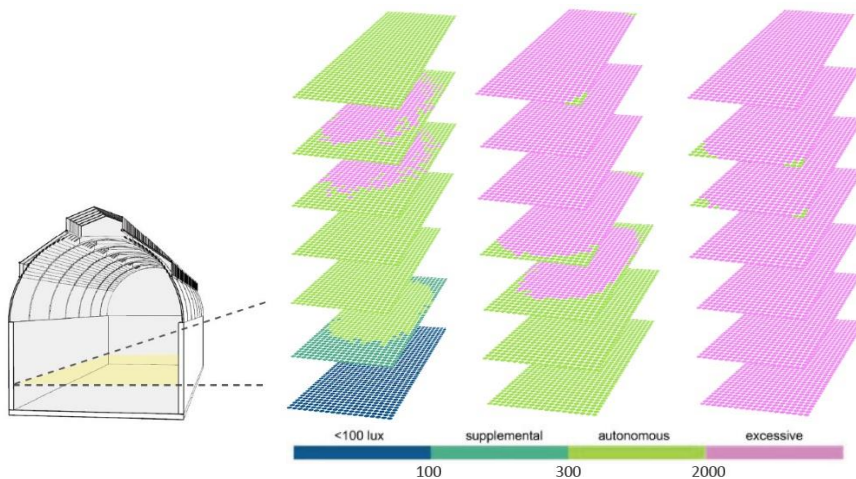


Figure 7. Useful Daylight Illuminance hourly data of winter, mid-season, and summer in the V&A museum

The daylight in winter falls under acceptable range in the first hour of the opening of museum. Later, few parts on the left side experience excessive daylight for two hours during the day. The few excessive hours indicate that a bigger problem is coming for summer days. The first half of a typical march day is under excessive daylight. The lux levels are tremendously high with over 3000 lux and in some hours more than 4000 lux. This could result in going above the exposure limits of a sculpture. Currently, every hour of the day is UDI over 3000 lux which has potential for glare and visual discomfort.

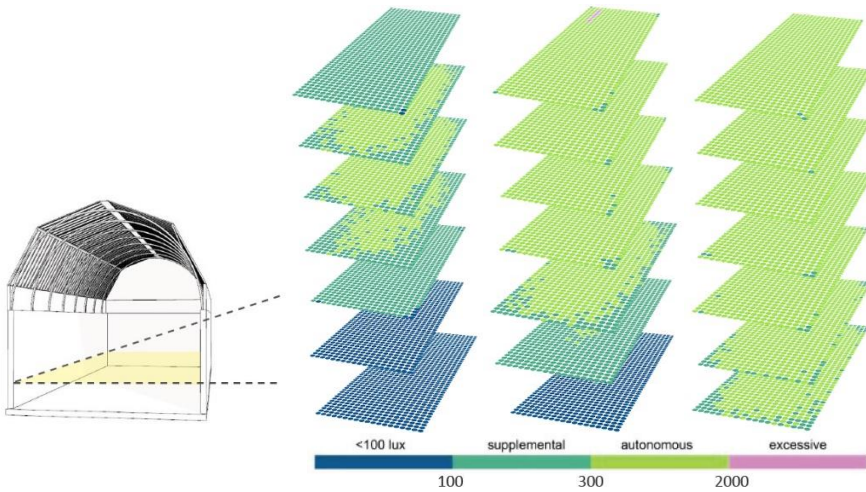


Figure 8. Useful Daylight Illuminance hourly data of winter, mid-season, and summer in the Natural History Museum

The use of double-glazed glass shows drastic shift in the scale while blocking partial sun. The winter time for roof type 2 falls under an acceptable range for sculpture spaces. The mid-season illuminance values are under autonomous range. But the range is below 800 lux throughout the day which is acceptable. The impact in summer is minimal and under the acceptable range throughout the day. The amount of light is controlled by the form and the structure of roof.

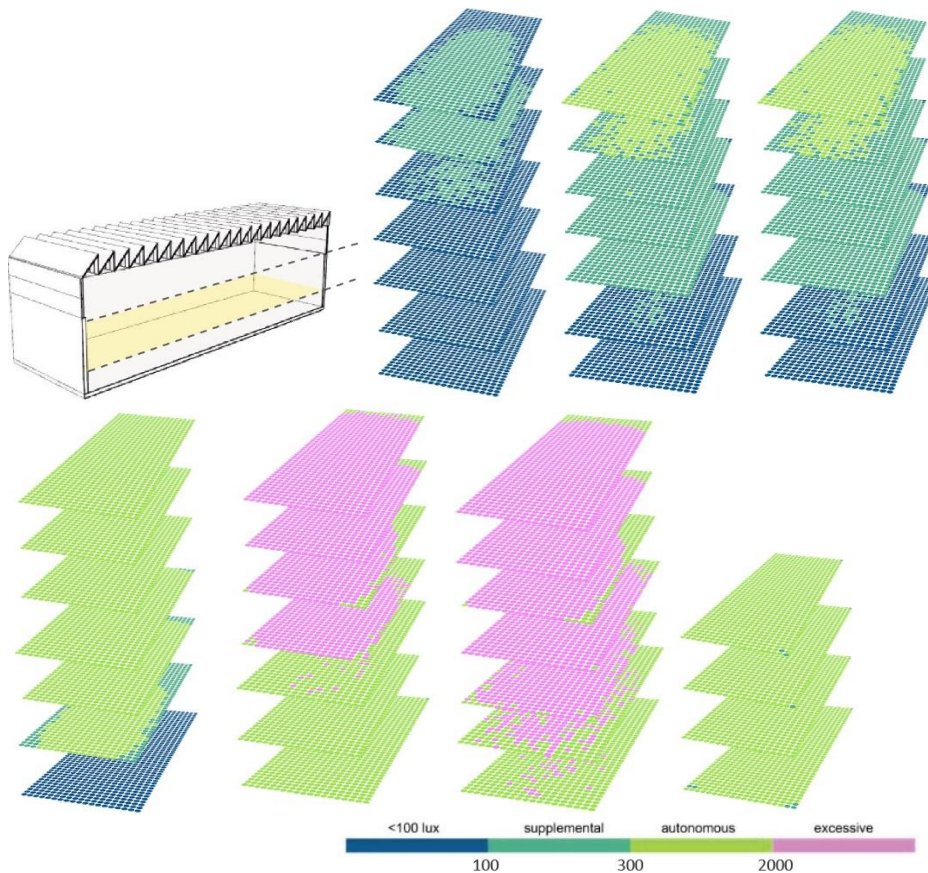


Figure 9. Useful Daylight Illuminance hourly data of winter, mid-season, and summer in the New Port Street gallery

The first iteration let's in a bare minimum of 10-150 Lux throughout the day. The minimum requirement of 300 Lux for a sculpture space is not being met and this is even more dangerous. In the case of second iteration, the initial hours receive the required Lux and few hours in afternoon still receive less than 300 Lux. For the second iteration, the illuminance range is finally acceptable throughout the day. However, if the roof fails to provide the targeted illuminance for more than half a year then the summer months don't justify the progress.

The second iteration let's in an illuminance of 1200 Lux throughout the day. As anticipated, the first iteration let's in an excessive amount of 400 Lux in the first half of the day during mid-season months. The rigid behavior of the roof light does not align with the varied behavior of London weather and the changing seasons. For summer, the first iteration allows 7000 plus Lux into the space throughout the day which is unacceptable. Both the iterations have the downside either in winter or in summer. The ideal solution to this problem would be to use the iteration two. In this way the winter and mid-season months are in the acceptable range. Later, for summer months incorporating blinds in the system would turn up to be beneficial.

5. Conclusions

Sawtooth roof design minimizes direct sunlight, reduces glare, and provides a consistent and even illumination throughout the day. With the incorporation of controllable blinds in the roofing system, this becomes the ideal roof type for museum spaces with building orientations restricted to north-south.

Monitor roof design allows light to enter from multiple angles, providing uniform illumination and reducing shadows. Monitor roofs are suitable for larger museum spaces with few sculptures to display as the daylight from this roof can create dramatic effect in the space highlighting the bespoke artefacts. As it also accounts for the ideal range of 200 lux in winters and reaches a maximum of 1000 lux for two hours in summers.

When selecting the ideal roof type, it's essential to consider factors such as the museum's architectural style, which is why skylight roof typology works ideally for the grandeur of the Victoria and Albert Museum as it can create a sense of magnificence and elegance in the space while allowing for controlled daylight with effective glazing density. It is the shading system underneath the roof that requires attention.

Here, the fixed louvers did not account for the ideal solution for V&A museum as winter days already observe an excessive 2500 lux in the space for few hours. A more flexible and adaptable shading system is beneficial in the changeable climate of London.

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