Luminous Environment in Le Corbusier’s Museum: 
An investigation of light in Chandigarh Museum in India and the Museum of Western art in Tokyo

STAVROULA YIANNAKOU¹, BENSON LAU²

¹,² School of the build environment, University of Nottingham, United Kingdom

ABSTRACT: Le Corbusier is one of the most well-known architects of 20th century and he is highly admired for using daylight as the basic design element to provide appropriate illumination to enhance spatial orchestration. Light in Le Corbusier’s domestic and religious buildings has been studied widely over the past years, but there is little research done on the luminous environment in his museum projects. Therefore this research aims to investigate the intriguing luminous environment in the Government Museum and Art Gallery in Chandigarh and the Museum of Western Arts in Tokyo. This study starts with a comprehensive qualitative appreciation of light in the museums and various techniques that Le Corbusier used to illuminate the space. In order to achieve a holistic understanding of the luminous environment of the museums, each case had been examined individually through selective quantitative analysis. In this part of the study, digital models had been used to examine different parameters concerning light performance in the exhibition spaces. This study concluded that through trial and error, Le Corbusier had consistently developed his museum lighting strategies over the years and there are good lessons on how to use daylight in the museums to be learnt from his projects.

Keywords: Museum environment, Spatial drama, Daylight

INTRODUCTION

Government museum and art gallery in Chandigarh
The museum of Chandigarh was inaugurated on 1968 and it is one of the most impressive buildings of the building complex in Sector 10 of Chandigarh. It is situated on the Jan Marg and has its entrance on the side of the Leisure Valley. The museum is placed on the far side of the plaza, surrounded by the Box of Miracles (theatre), the art gallery pavilion and the art college. It has been described as “… the building of overwhelming power and majesty, by an architect of international prestige, did not anyway resemble traditional exhibition galleries, and presented many problems of scale, and the type of requirements for exhibition of the art objects safely and effectively”. [1] The design of this building was based on the idea of the museum of the Unlimited Growth where a square spiral form is the dominant feature. The internal spaces are organized as a spiralling ramp that takes visitors through the building.

The National Museum of Western art in Tokyo
Located at the right side of the Ueno Park in Taito in Central Tokyo, the National Museum of Western art is being a part of the museum and zoo complex. It is the third museum that was designed based on Le Corbusier’s idea of unlimited extension and comprises the only national institution devoted to western art. As Le Corbusier was not in Japan at the time of the construction, he worked with Kunio Maekawa, Junzo Sakagura and Takamas Yoshizaka who were his apprentices and the building was completed in 1959.

METHODOLOGY

In order to explore in detail the luminous environment in Chandigarh Museum of India and the Museum of Western art in Tokyo designed by Le Corbusier, the two buildings were examined individually, but the method of exploration and evaluation adopted was the same. The research started by investigating the spatial sequence, the interior arrangement and then the study expands to the qualitative analysis of the fenestration design.

Subsequently the two exhibition buildings were simulated in Ecotect/Radiance Software for quantitative investigations where at first place the daylight performance had been investigated. This was then followed by the annual daylight illuminance studies. Other testings include the uniformity ratio that reveals the distribution of light in the space and the brightness contrast which has direct connection to visual comfort. The results were compared with the recommended values given by CIBS lighting guide that is based on the light sensitivity of the objects and with the SLL Lighting Handbook.
LUMINOUS ENVIRONMENT IN THE GOVERNMENT MUSEUM AND ART GALLERY IN CHANDIGARH

Architectural promenade

The exterior of the building is simple with brick-tile cladding on the external surfaces combined with exposed reinforced concrete, built on columns. The plan is relatively simple and is based on a grid of 165 feet by 165 feet. Vertically it consists of three floors and the spaces are flowing into one another, allowing long and deep uninterrupted views. This specific arrangement of the space derived from Le Corbusier’s concept to create events and encounters at every step and corner providing in this way unusual perspectives of the exhibits.

The entrance is located at the centre of the complex on the ground floor and leads to the main hall where there are several sculptures and paintings. The ground floor is partially enclosed and comprises the reception hall, workshops, the cafeteria, the space for storage and the lecture hall which is a detached structure. The principal exhibition area is on the first floor and is accessible by the ramp of the triple height entrance hall on the ground floor. The second floor is arranged as a bridge that covers only a portion of the first floor and it consists of administrative, curatorial and research offices, a committee room and a library. Figure 1 shows the spatial sequence in the museum. The museum was designed in a way that there were no walls to separate exhibition spaces. The height of the ceiling and pillars differs, allowing a free flow of space to take place.

Fenestration design of the Government museum and Art gallery in Chandigarh (Qualitative analysis)

The exterior is very simple with minimum windows. Starting from the side windows we do not observe any special facade treatment by the architect to suit different orientation, as there is no difference between the North-West elevation and the South-East elevation. The principal source of light on the first and second floor is introduced via a rectangular window 6.50 meters wide and 2 meters height with sunlight louvers that control the incoming light. Additional light enters form the vertical transparent windows that run continually thought the entire height of the first and second floor. Focusing on the North East and South-West elevation, we observe that accordingly to the other two elevations referred above, they are very similar. In these two elevations the same type of the rectangular window is repeated on the first and second floor with additional vertical louvers. Similarly, the ground floor consists of full glazing windows.

Additional light is introduced via a skylight structure that contains clerestory openings on its north-east and south-west sides. The glazing part of the structure is recessed as is it be shielded by a horizontal plane that is running from the roof of the skylight. This specific structure is repeated with no exception along the entire roof of the museum and thus there is no special treatment in any specific gallery area. Thus, direct diagonal sunlight strikes on the upper part of each wall which becomes a source of reflective light for the exhibition.

The luminous environment in the Government Museum in Chandigarh (Quantitative analysis)

Daylighting Performance

Daylight factor (DF) results indicate the quantity and distribution of light under overcast sky conditions. N. Baker in Architecture and Daylighting recommended that spaces with a daylight factor greater than 5% can be considered as a well daylit space while spaces that are achieving less than 2% would need artificial lighting as supplementary light source [2]. In addition, Mark Fontoyont stated acceptable DF values for work of art in Europe are between the range of 0.5% to 2.0 [3].

According to the above recommendations, the initial results from Ecotect/Radiance analysis show that the museum in Chandigarh is generally inadequately lit as the DF values are far below 2%. As it is shown on Figure 2, on ground floor there is a great difference in values as daylight factor ranges from 11% on the north-west side to 1% just outside the principal exhibition hall. In contrast with the reception area which has an average daylight factor of 2.29%, we observe that the main exhibition room receives lower daylight illuminance all over the main hall. Since there is no significant difference between the DF values, it means that there is a uniform distribution of light. However the average Daylight factor is below 1% indicating artificial lighting is required most of the time in this space. The luminous environment along the transition from the reception area to the principal exhibition space has a radical change in
the illuminance level which on the one hand, signifies the entrance to the principal exhibition, on the other hand may induce uncomfortable high brightness contrast.

Low illuminance level has also been observed over the gallery of the first floor as the average daylight factor is about 1% which also indicates the top linear skylights may not be able to introduce adequate light into the middle part of the gallery. Figure 3 below shows the Daylight Factors distribution curve which was overlaid on the section of the building.

**Uniformity ratio**

The uniformity ratio is defined in the CIBSE Lighting Handbook as the minimum value of Daylight factor that is measured on a relevant working plane, divided with the average daylight factor of the room. According to the recommendations the optimum values in a room should not be less than 0.7 in order to achieve even distribution of light[4].

By analysing the simulation results based on above criteria, it has been observed that all the values are below the recommendations, with the reception area having the lower ratio of 0.18. Here it is important to note that not only the daylight factors are extremely low, the uniformity ratio over the main exhibition hall is also moderately low and consistent, indicating an uneven distribution of light. The simulation results are summarised on the following table (Table 1).

<table>
<thead>
<tr>
<th>Area</th>
<th>Uniformity Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main exhibition hall</td>
<td>0.43</td>
</tr>
<tr>
<td>Gallery first floor</td>
<td>0.40</td>
</tr>
<tr>
<td>Reception</td>
<td>0.18</td>
</tr>
<tr>
<td>Gallery 3rd floor (S-W side)</td>
<td>0.43</td>
</tr>
<tr>
<td>Library 3rd floor</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Daylight Illuminance**

Examining the illuminance levels over the main exhibition area, it has been observed that the light levels are in general low except certain points on the ground floor. The main source of light comes from the fully glazed south-west elevation rather than from the skylights on the roof. As the light enters from the side it strikes directly on the sculptures that are placed just below the columns, creating dramatic contrast (figure 4). In this gallery space, the zone up to 2 meters from the floor proved to be very bright compared to the zone above 2 meters, where we notice that the illuminance values suddenly drop. The high illuminance contrast may potentially cause visual discomfort here. When examining the light coming from the skylights, we observe that once the light enters the space it falls over the wall just below the skylight creating patches of light especially in winter where the angle of the sun in lower, thus this skylight does not direct sufficient light into the main exhibition area.

Low daylight level can also be observed inside the picture galleries on the first Floor. The recommended illuminance value for painting display in the CIBS lighting guide Museums and Art Galleries is 150 lux. It has been observed that for the main display wall on the South-West, the light level is lower than the recommended value. In addition, at certain times of the year (like in the afternoon of December), the top skylights bring in patches of light creating a horizontal zone of high illuminance levels over the main display wall.
This phenomenon firstly may cause deterioration of the paintings and secondly may have adverse effects on the visual perception. The simulation results described above reveal that the linear skylights in this museum may not effectively contribute to the illumination of the art work, especially at the gallery space on the South-West side of the museum, also they might be potentially a glare source as well.

Extremely low illuminance values were observed over the North-West side of the gallery, indicating that this part of the gallery is not adequately daylit. However light level found in the South-East side of the gallery on the first floor are close to the recommendations most of the time.

Luminance ratio
Luminance ratio help to quantify the brightness contrast. Hence this was used to estimate the contrast between the selected visual tasks (exhibition objects) and their surroundings to reveal the brightness contrast ratio. Hopikinson suggest that the optimum luminance ratio should be 10:3:1 of the visual task to immediate surround to general surround [6].

For the luminance ratio analysis the immediate background was defined as a 30° visual cone from the eyes of the observer. In figure 5, the circle in the images indicates the immediate surround. The average value of the luminance readings taken outside the circle represented the luminance value for general surround. The centre of the circle is the focal point. The experiments were carried out in the main exhibition hall for equinox under sunny sky conditions as sunny sky is dominant in Chandigarh. The results are demonstrated on figure 5.

![Figure 5: Results for the luminance ratio analysis for the Chandigarh Museum, table from –author 2011](image)

For position A, we notice that the task to immediate surround is 1:1.16 and task to general surround is 1:4.48. These ratios are within the recommended luminance ratio of 10:3:1 meaning that the brightness contrast in the room is acceptable. For position B we observe that the luminance ratios are in reversed order. The background proved to be brighter than the task which is the object. The Luminance ratio for the task to immediate surround is 1:23 and task to general surround 1:39. The highly illuminated background causes visual distraction and de-emphasizes the sculpture. Thus it is obvious that the glazing façade of the South-west side of the gallery develops a zone of excessive high brightness, making the displayed objects hardly visible.

**THE NATIONAL MUSEUM OF WESTERN ART IN TOKYO**

**Architectural Promenade**
The external envelope of the building is relatively simple with carefully positioned openings. The ground floor is raised on pilotis and consequently the entrance is approached through a landscaped plaza. Focusing on the internal arrangement, the space is organized as square open plan of 46x46 meters. By entering the main entrance at the ground floor the reception area leads straight to the central gallery that is a double-height court which is the principal exhibition area. From that point the smaller galleries radiate up and out. The central gallery that is under the name of 19th Century hall contains Sculptures by Robin. The light in this part of the museum is coming through a triangular skylight. The museum contains rectangular helix shaped exhibit galleries and spiral staircases. The second floor exhibition gallery has as shape of a rectangular helix and is connected to the first floor via a slope. The ascent to the painting galleries via the promenade affords a continually view of the exhibits placed in the main gallery providing an enjoyable change of space perception while rising. Around the perimeter the ceiling is raised up to the height of two story’s increasing in that way the attention of the observer to the displayed paintings on the adjacent wall. The connection to the upper floor is through the main staircase on the North-West side that leads to the third level. The spatial sequence in this museum is shown in figure 6.

**Fenestration design of the Museum of Western Art (Qualitative analysis)**
Starting from the 19th Century hall, it has been observed that the main light source is a 6 meter, triangular and tent like, pyramidal skylight intersected with white smooth...
concrete finishing on beams and a cylinder column. This special shape of the skylight helps to temper the brightness of the incoming light. The glazing aperture of the skylight was deliberately placed on the north side of the gallery to provide even distribution of light, whereas the other three sides of the skylight remained closed. Adjacent to the skylight, there is another smaller linear skylight that runs along the whole small side of the room providing additional overhead illumination.

Long rectangular skylights illuminate the smaller galleries. Significantly the light is provided via four lighting troughs positioned above the main core of the main gallery, respecting the rectangular shape of the plan. The skylight protrudes 1.5 meters above the museum roof with openings on the sides. The gallery under the skylight works as an intermediate space which admits light to the connected exhibition space of the first floor. At the North-East side of the ground floor the elevation is completely glazed. Vertical internal louvers had been added to control any implicit conditions derived from high light sources. Clear glazing had been used on the frond façade of the main entrance of the museum. Focusing on the four elevations of the building, we identify a repetition of window typology which a recess is created to act as an overhang.

**The luminous environment in the museum of Western Art in Tokyo (Quantitative analysis)**

**Daylighting Performance**

Based on the simulation results taken from the daylighting performance analysis, it has been observed that the day light level in the reception area is insufficient as the average daylight factor is only 0.62%. However, as shown in Figure 7, the DF values right over the entrance of the reception area is 2.8% and then it drops gradually. Thus, the reception area works as a transition zone with gradual decreasing illuminance level which helps the visitors adapt their vision from high brightness zone to the low brightness zone which is the exhibition rooms. The visitor then proceeds on the 19 century exhibition hall where the Daylight values range from 2% to 2.5% where artificial lighting may require at times to enhance the luminous environment. In contrast, the cafeteria proved to be the brightest space with average daylight factor of 7.7%, but there is a great variation of daylight level here (See Figure 8 and Table 2).

**Uniformity ratio**

The daylight simulation results indicate that the 19th Century hall has even distribution of light since the uniformity ratio is 0.61 which is close to the recommended uniformity ratio of 0.7. The interplay of the linear and triangle skylights helps to spread even light over the exhibition space. The uniformity ratios in different spaces are presented in Table 2.

**Daylight Illuminance**

When examining the daylight level of the main exhibition hall under overcast sky condition, it has been observed that in the winter the space is dark as the values are mainly less than 100 lux and artificial light is required. Moreover certain parts of the hall, like the wall surfaces under the linear skylight and the supporting column under the triangle skylight seems to be comparatively brighter. The light level at these points is exceeding 300 lux. Generally speaking, the center of the hall is well illuminated. Daylight coming from above reveals the sculptures as it spills into the center of the gallery and then it softens towards the corners of the room. Moving from the gallery of the first floor, it has been observed that under overcast sky conditions the light levels in the main exhibition spaces on the south-east and north east side are below 75lux thought-out the yea. In contrast the illuminance levels on the south-west
side appear to be adequate as they range from 75 lux and 150 lux.

In addition to the daylighting performance analysis under overcast sky condition, simulations had been conducted under sunny sky conditions to investigate the worst case scenario. As shown in Figure 9, sunlight entering from the skylights in winter mornings creates a high brightness contrast in the gallery spaces.

**Figure 9: Diagram of illuminance distribution, sunny sky conditions at 12 o’clock in December, diagram from–author, 2011**

**Luminance ratio**

The luminance ratio studies were carried out in the main 19th century hall and the results obtained from 3 viewing positions are shown in Figure 10. The simulations were conducted under overcast sky conditions as the dominant sky condition is cloudy.

The luminance ratio between task to immediate surround for position A is 1:1.1 and that for task to far surround the and 1:3. It is clear that the values are within the recommended luminance ratio of 10:3:1. However it is obvious that the first ratio shows the task and background light are having similar brightness, indicating that the incoming light does not highlight the three dimension quality of the objects.

**Figure 10: Results for the luminance ratio for the National Museum of Western Art, figure from –author, 2011**

**CONCLUSION**

By comparing the results of the two museums, we notice that the luminous environment of the museum of Western art in Tokyo is far better than the museum in Chandigarh which is evident that Le Corbusier has learned from the mistakes he made in museum in Chandigarh and further developed his museum lighting skills. In the Museum in Chandigarh, the present study concluded that an inappropriate luminous environment has been designed to light the exhibits. The design of the rooflight is similar to the treatment in industrial buildings, thus it provides even distribution of light which does not enhance the three dimensional modelling of the art objects. Moreover this rooflight creates incidental sun patches that they potentially may cause glare. In addition, the fenestration design does not provide adequate illumination for the gallery space. On the contrary, the internal luminous environment of the museum in Tokyo is better controlled because of the design of the skylights. The simulation results show that the main exhibition space is well daylit most of the time. However, the luminance studies indicate that there is not enough brightness contrast provided by the window apertures under overcast sky condition, but under sunny sky conditions the three dimensional modelling of the art objects is better revealed. Figure 11 summarizes the comparative analysis the lighting ideas in the two museums.

**Figure 11: Skylights and comments, figure from –author 2011**

**REFERENCES**