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Understanding the Relationship Between Daylighting and Spatial Character: A Case of two Museums in Gujarat

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ABSTRACT

Museums preserve, exhibit and communicate the socio-cultural heritage of our societies. They narrate stories of people, places, events and phenomenon through representations, interpretations and experience of the past, present and future through medium of art, artefact and various forms of display. The architecture of museums includes design of exhibition spaces for curated display of cultural objects and creation of a spatial experience which engages visitors in a visual and psychological experience of its environment. Daylighting is an integral aspect of museum design which enhances the experience of space, provides visual comfort and helps in clear perception of its exhibits. This paper investigates the relationship of daylighting, spatial character and form of two museums of Gujarat; one belongs to the colonial times and the other to the modernist period. By adopting the method for visual evaluation of light in space, developed by professor Anders Liljefors at the KTH School of Architecture in Stockholm, light is analyzed in both qualitative and quantitative manner. Studying both aspects of light provides an insight into the impact of light on space perception in museum galleries. Eight visual attributes of light which contribute to spatial experience of light are used for analysis: light distribution, light level, light patches, shadows, glare, specular reflection, colour of light and colour of surface. Through a comparative analysis of two distinct attitudes to daylighting strategies in museums of two different time periods, the study reveals an evolution in relationship between spatial experience and lighting design in museums and a shift in the conception of how light shapes museum spaces.

KEYWORDS: Museums, Daylighting, Space Perception.

1. INTRODUCTION

In architecture, the presence or absence of light has impacted perception of spaces. Along with other multisensory experiences, the visual aspect of spatial experience is made possible by perceiving spaces in light. Vision being a preliminary source of collecting information about the surrounding builds a perception of the surrounding in our mind. Visual experience is shaped by different attributes of light like brightness, intensity, colour of light and light distribution. Amount of light and the quality of light in the space impact visual perception and varying attributes of light generate a variety of spatial experiences.

The way light integrates with space has a direct impact on the perception of the space. What we see, experience, and interpret the space is affected by how light interacts with us and the environment [3]. The dynamic character of daylighting and controlled artificial lights affects not only the physical characteristics of the space but also provokes different visual experiences and atmosphere of the space [3]. Light is the fundamental intangible material for architecture and it plays a significant role in the quality of architecture.

While daylight contributes to the overall ambience of space, it has a negative impact on artefacts in the museum. Thus, daylight and preservation of artefacts are often in conflict while designing daylighting for museums [9]. Architects and lighting designers have explored various strategies for daylighting design in museums and art galleries which balances the functions of both aspects, daylighting and preservation.

1.1. LIGHT AND SPATIAL CHARACTER

Lighting is defined by its physical and visual aspects according to Professor Ander Liljefors. Physical aspects of light are quantifiable and measurable, such as light level, daylight availability, glare etc. Instruments and software simulations can be used to take such measurements. There are visual aspects of light that impact experience and space perception. Understanding light as a whole is a complex field as light affects our perception in both, physical and visual ways [3].

Study of the visual experience of light demands attentive observations. The concept of perceived light denotes attentively observed light. These concepts are described in the project named, Perceptual Spatial Analysis of Light and Colour, such as light level, light distribution, shadows, light patches, reflections, glare, the colour of light and the colour of the surface [4]. We distinguish impressions of space, form, colour, texture, material etc. with the distinct quality of the above concepts of light and its relationship with space. Such observation coherently builds the perception and character of space.

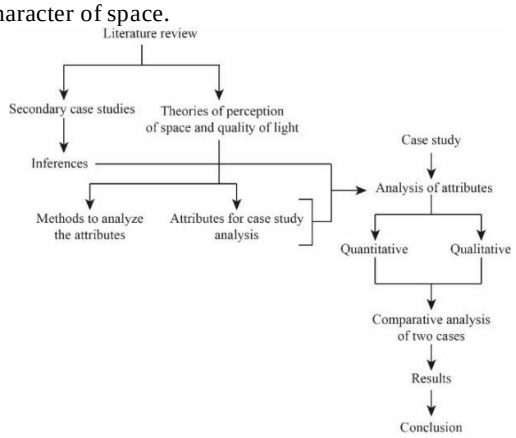

Fig. 1. Framework of the research

2. METHDOLOGY

The case study is analyzed adopting the method for visual evaluation of light in space, developed by professor Anders Liljefors at the KTH School of Architecture in Stockholm. Attributes of light are analyzed in quantitative and qualitative manner. Visual aspects of space are described with reference to the role of light in defining the spatial character. A. Liljefors gives classification of visual aspects of space in terms of spatiality, atmosphere and visibility [3].

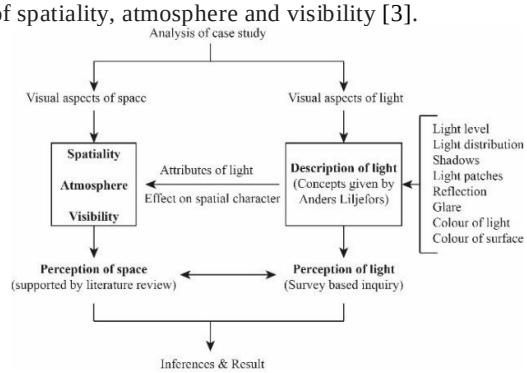

Fig. 2. Analytical framework for case study

2.1. SPATIALITY

Spatiality is the possibility to define the physical characteristics of the space. It includes physical and measurable aspects such as volume, proportion, distance and orientation. All four attributes are influenced by lighting and we perceive spatiality according to the lighting quality and quantity in physical space. Marrieta M. talks about light and space in her book *Light Revealing Architecture* that discusses the relationship of light with spatial boundary [6].

Perception of volume because of the bright central skylight in Guggenheim Museum is very different from the Holocaust tower in Jewish Museum. Guggenheim museum is perceived as spacious because of the daylight washing the walls of the circulation ramps. In Jewish museum, absence of light at the top of the entrance stairwell gives feeling of void and infinite volume.

Fig. 3. Guggenheim museum Central skylight-Radial orientation

Source: https://www.guggenheim.org/the-frank-lloyd-wright-building

Light in Kimbell art museum defines linear orientation of the gallery whereas the central source of light establishes centrality of the atrium in the Guggenheim museum. Pantheon is also one of the prime example of how daylight gives orientation to the space. In these examples light defines the symmetry and asymmetry of space leading to the perception of visual balance or imbalance of spatial character.

Fig. 4. Jewish Museum **Fig. 5.** Kimbell Art Museum

Source:
Fig. 4: https://www.ianbramham.com/
Fig. 5: https://medium.com/@priji

The attributes of light such as light distribution, sharpness of light and shadows, reflection of light, light source and direction of light also play major role in defining spatiality.

2.2. ATMOSPHERE

Atmosphere of space is defined as the psychological mood that is driven by lighting. We feel cheerful, calm, boring etc. depending upon the lighting quality of space [4]. Hues and shapes, and light and dark, contribute to the production of a particular atmosphere through lighting. Atmosphere is always subject to transformation. Change in position in space and in light quality results in a change in atmosphere.

Fig. 6. Chichu Art Museum **Fig. 7.** Louvre,Abu Dhabi
Source:
Fig.6: https://in.pinterest.com/pin/9922061663802584/
Fig.7: https://www.archdaily.com

Atmosphere created by lighting defines the level of intimacy in space as per the theory of Atmospheres by Peter Zumthor. Lighting can create an intimate atmosphere in museums as seen in the Chichu Art Museum designed by Architect Tadao Ando whereas it creates a dramatic atmosphere in the Louvre museum, Abu Dhabi. Influence of light on atmosphere of museums depends on interrelationship of parameters like connection to outside, movement patterns, layout of artefacts and lighting quality.

2.3. VISIBILITY

Visibility is associated with the functional aspect of light. Visibility is the measure of possibility to see things. Visibility of space is perceived through form, surfaces, texture, colour and light [3]. Light is the main attribute which helps to build our vision to see the surroundings. We can perceive the physical attributes of space as well as atmosphere created by light. Visibility gives us the idea of identification about various materials, their textures and colours.

Light defines the form of the space, and we perceive the form through our ability to see it. Visibility is associated with functional aspects and it influences the functionality of spaces. The way we move, the way our eyes move in space is largely influenced by the visual aspects of light. In museums, light creates focus, light guides movement, light emphasize form and material which builds perception of space.

3. CASE STUDY INTRODUCTION

3.1. BARODA MUSEUM & PICTURE GALLERY, VADODARA

Baroda Museum and Picture Gallery was founded by Maharaja Sayajirao Gaekwad of Baroda in the year 1894. The museum is a part of Sayaji Baug, which is located near Maharaja Sayajirao University in the Sayaji ganj area.

The Museum was designed by British architects R.F. Chisholm and Major R.N. Mant. The Baroda Museum is a two storied buildings built in the Indo-Saracenic style of architecture. General design of the museum building follows the local Maratha tradition of using a wooden framework and brick walls.

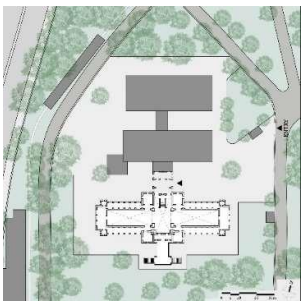

Fig. 8. Baroda Museum, Vadodara

3.2. L. D. MUSEUM, AHMEDABAD

Lalbhai Dalpatbhai Museum also known as L.D. Museum was founded in 1984. It was designed by Ar. B.V. Doshi and follows a modernist style of architecture. The museum is a part of L.D. Institute of Indology, which researches and preserves manuscripts and works of ancient Jain literature, paintings and sculptures.

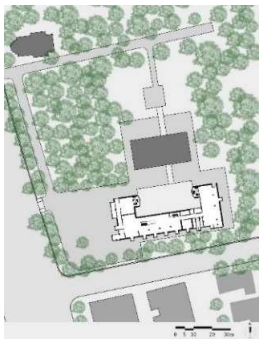

Fig. 9. L.D. Museum, Ahmedabad

4. ANALYSIS OF BARODA MUSEUM

4.1. SPATIAL ANALYSIS

First floor gallery of the museum is considered for analysis which consists of displays related to zoology, musical instruments, ethnology and mineralogy. In the cross shaped plan of the museum, longer axis extends towards the East-West direction whereas shorter axis is towards the North-South direction.

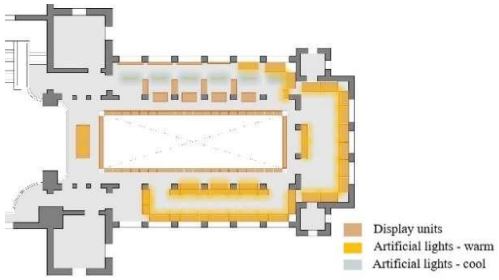

Fig. 10. First floor gallery, Baroda Museum

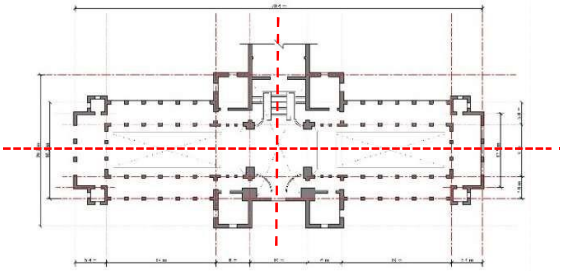

Fig. 11. Orientation and proportions

The museum has three levels of fenestrations illuminating the inside volume. Ground floor fenestrations serves to the galleries on the ground floor periphery. Fenestrations on first floor are 1.8m x 2.4 m following a structural rhythm and illuminating the galleries as well as the entire volume of the museum. Windows have frosted glass glazing in wood framed shutters. Curtains are installed to reduce the brightness whenever required. 1m x 1.6 m Dormer windows contribute to the overall illumination. Dormer windows are fixed glass windows with the glazing of frosted glass painted on external surface.

Fig. 12. Fenestrations at different levels

Volumes of galleries are defined by the spatial boundaries and elements that create enclosure. The entrance hall (1) is of full height of 15 m. Bridge at (2) divides the entrance hall and east-west galleries (3). (4), (5), (4a) and (5a) are the peripheral galleries on ground and first floor respectively.

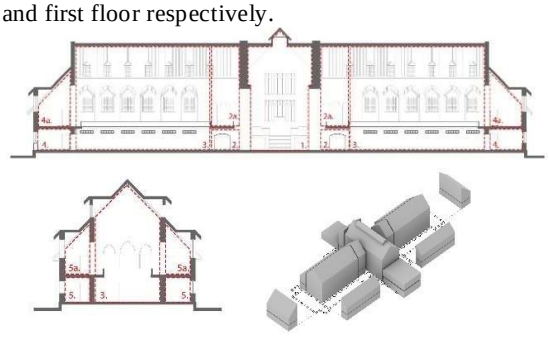

Fig. 13. Volumes

4.2. ANALYSIS OF LIGHT

4.2.1. LIGHT LEVEL AND DISTRIBUTION

Higher illuminance is observed in galleries. Varying light level in the plan and section shows the daylight is the generator of atmosphere. Avg. lux reading is 277 lux in galleries. Large multiple windows and multi-level fenestration facilitates the space with higher illuminance and even distribution of daylight.

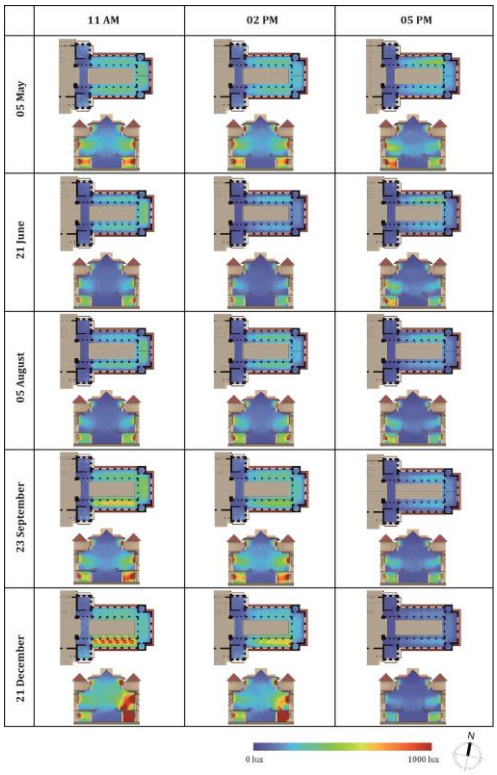

Table. 1. Illuminance simulation, Baroda Museum

4.2.2. SHADOWS

Structure and ornamentation complexity results into the play of shadow and bright areas. Daylight is filtered through the frosted glass of the windows, which prevents the harsh sunlight inside the gallery. Therefore shadow quality is soft and blur.

4.2.3. LIGHT PATCHES

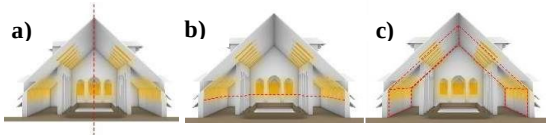

Fig. 14. a) Symmetry **b)** Spatial Boundary **c)** Form

Light patches on first floor are filtered by structure as we move inside the gallery. Patches of dormer windows are not directly visible, the reflected light from adjacent wall is visible in rhythmic pattern following the structure. Light patches on windows results into glare.

4.2.4. GLARE

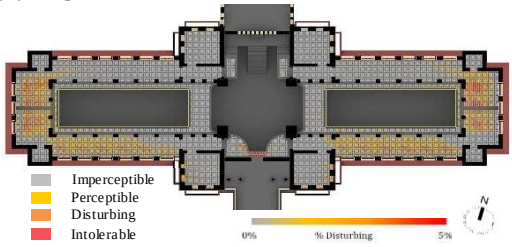

Fig. 15. sDG simulation, Baroda Museum

sDG (Spatial Disturbing Glare) is 0.6%, views with disturbing glare > 5% of time. There are fenestrations facing all four directions and directly opening into the gallery, glare can be experienced from any orientation depending upon the time of the day and orientation of sun. Disturbing glare zone is higher in galleries, it almost covers the east, west and south galleries.

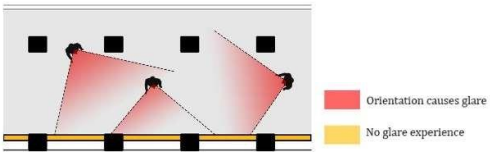

Fig. 16. Orientation and Glare

4.2.5. REFLECTION

Reflection in the museum causes visual discomfort. Higher illuminance and multiple source of daylight create reflection in the glass casing of display units. This also depends on layout and orientation of the display units and the position of the viewer.

The display units in the passage facing upwards have higher reflection of the roof because of the daylight which results into the glare.

Fig. 17. Reflection in galleries

4.2.6. COLOUR OF LIGHT AND SURFACES

Colour of surfaces are perceived as varied. Three hues are dominantly present in the space. Beige colour paint is applied on all the masonry walls, with smooth and matt finish. First floor Flooring and ceiling has a dark green hue, whereas the floor is slightly glossy. Wooden furniture, railings, display units are painted and polished in a dark brown colour. Colour of light gives warm render to walls when juxtaposed with the wall colour and cool colour render with floor, creates contrast in colour render of the space.

Fig. 18. Colour of surfaces

5. ANALYSIS OF L.D. MUSEUM

5.1. SPATIAL ANALYSIS

The first floor has a central gallery which is oriented in the east-west direction. It houses Jain paintings and manuscripts, wooden carved artefacts, bronze sculptures, textile artefacts and paintings.

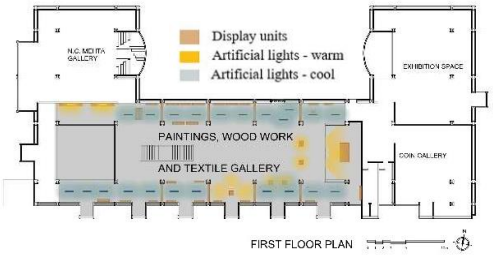

Fig. 19. First floor gallery, L.D. Museum

The structural module is 6 m x 13.2 m with further division of three bays of 2.8m x 7.6m x 2.8 m. In section, clearstory windows are 5.5 m high from the first floor level.

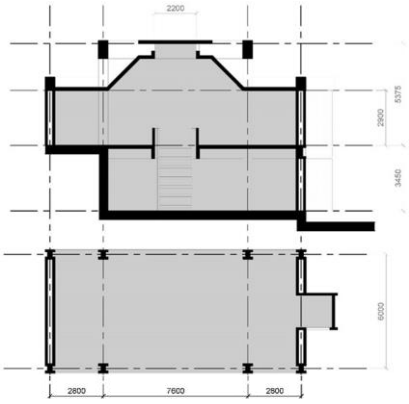

Fig. 20. Proportion of the spatial module

Two approaches to fenestration design is observed which allows daylight inside the gallery. Clearstory windows on the monitor roof reflects skylight in the gallery eliminating direct sunlight. Fenestration on south façade have opening facing west, which allows evening sunlight into the space. Articulation of fenestration reduces the intensity of daylight and reflects diffused light into the main gallery. Clearstory window has glazing of frosted glass and wall fenestration does not have glazing.

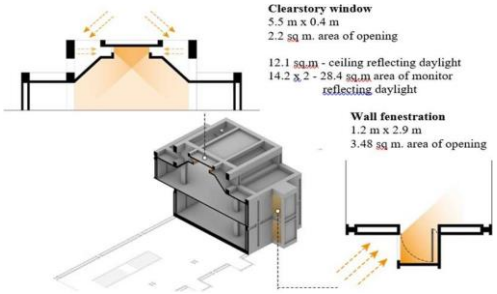

Fig. 21. Fenestration design

Entrance porch (1) is 2.7 m high and guides indirect entry to the museum. Entrance hall (2) is double height volume of 8.82 m. The galleries (4) and (5) are divided on two levels.

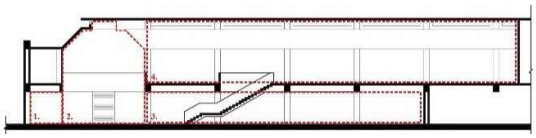

Fig. 22. Hierarchy of Volumes

5.2. ANALYSIS OF LIGHT

5.2.1. LIGHT LEVEL AND DISTRIBUTION

Daylight enters the gallery in a controlled manner. Preservation of artefacts is of prime concern and design of daylighting has been consciously undertaken. Reduction in light level is achieved by reflected daylight integration through monitor and clearstory windows.

Fenestration design on south facade is such that it allows indirect daylight throughout the day. Wall fenestrations and monitor roof controls the light level in the main gallery.

Light distribution is non uniform for daylight at certain points in time in the space because of limited number of fenestrations. North aisle of the gallery does not receive daylight in sufficient amount. Uniformity in light level throughout the day and year is achieved through daylight design strategies.

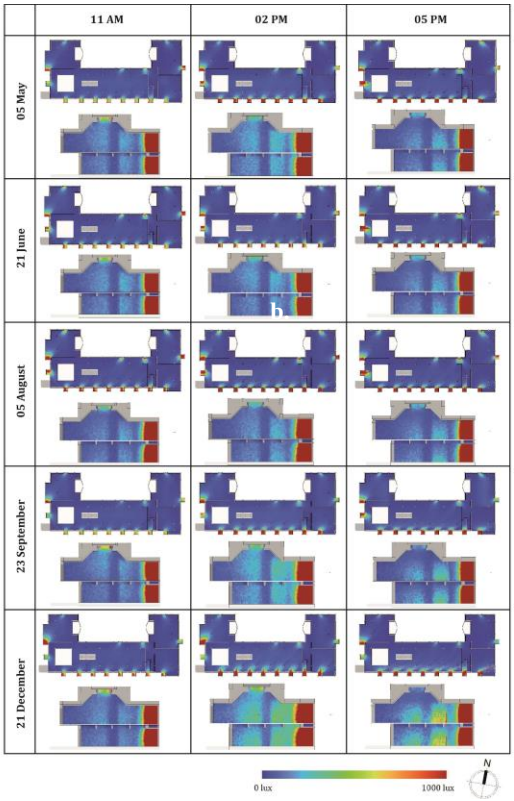

Table. 2. Illuminance simulation, L.D. Museum

5.2.2. SHADOWS

Shadows in the gallery are soft. Direct sunlight is received only in fenestration area on south façade. It shows the absence of sharp shadows in the main gallery due to daylight. It results into the soft edges of structure and built form.

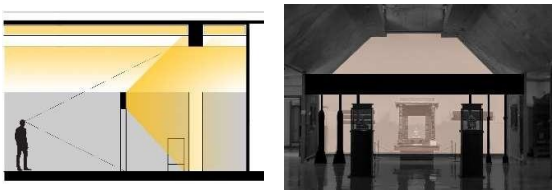

Fig. 23. Silhouette effect

5.2.3. LIGHT PATCHES

Light patches create focus in the gallery. Light patches from reflected skylight on the monitor ceiling accentuate linear orientation of the space. Artificial light and colour of the wall creates bright patch in the gallery, which contributes in the perception of depth in the gallery. Light patches in the gallery guides movement of people and the movement of their eyes.

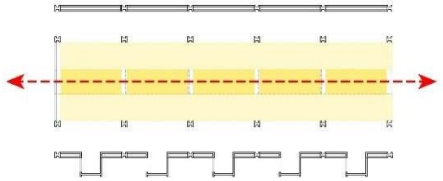

Fig. 24. Light patches and Linear orientation

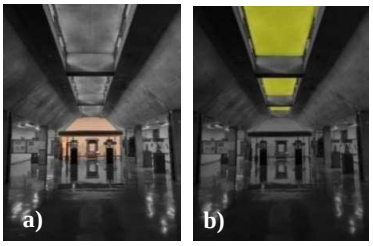

Fig. 25. Light patches **a)** Artificial light **b)** Daylight

5.2.4. GLARE

sDG (Spatial disturbing glare) suggests 2.8% of the views results in the glare as per the simulation result. Design of the gallery and movement in gallery is not disturbed because of the articulation of fenestration on south façade. Articulation is such that maximum possibility of glare is controlled within the area of fenestration.

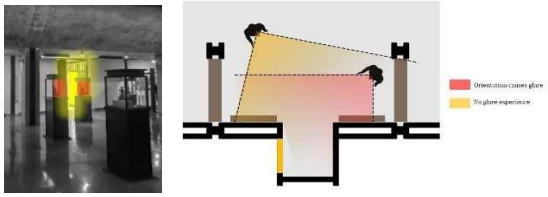

Fig. 26. Orientation and Glare

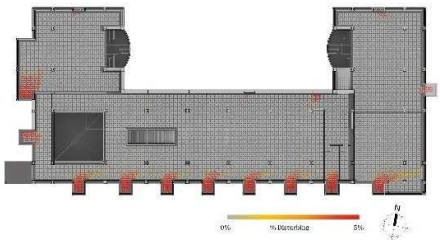

Fig. 27. sDG simulation, L.D. Museum

5.2.5. REFLECTION

Kota stone with undulating glossy finish creates reflection of space in the museum. Reflection enhances spatial character as it adds depth to the volume. Reflection of daylight from rough surfaces of exposed concrete structure plays role in diffusing the daylight and spread it evenly in the gallery.

Fig. 28. a) Rough surfaces **b)** Glossy surface

5.2.6. COLOUR OF LIGHT AND SURFACES

Coherent colours of surfaces create calm and intimate atmosphere without much dramatic effect in the space. More than 80% of the visual field is in grey colour. Grey surface colour plays major role in reducing the daylight intensity in the gallery. It results into the significant drop of light level.

Surface colours are associated with visible aspects of space perception. Grey colour with glossy finish represents floor and grey colour with rough finish is perceived in structure. White painted walls provide background for the artefacts and in spatial aspect, it extends the visual boundaries on north and south side of the gallery.

Fig. 29. Identification of the color palette in gallery

6. RESULTS AND DISCUSSION

Role of daylighting in visual space perception can be discussed in three aspects as discussed earlier, Spatiality, Atmosphere and Visibility. Role of different attributes of daylight in defining spatiality, atmosphere and visibility is identified in each museum by comparing inferences from the analysis.

Survey was carried out to understand people's perception about attributes of light in museum. Students of Architecture school participated in the survey and gave their idea about how they perceive light in the museum. Difference in glare and reflection is easily perceptible for both the museums. Baroda museum is perceived as brighter than L.D. Museum. Shadows and glare are neutral and not creating contrast or disturbing the visual perception. Color of surfaces are more varied in Baroda museum.

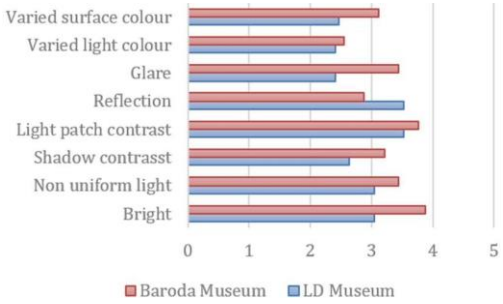

Fig. 30. Survey results

6.1. SPATIALITY

Light creates space within a space. Light level defines spatial boundary of the gallery as a whole. Light level and distribution illuminate the overall space for general lighting purpose in Baroda museum. Light distribution responds to the functional aspect with central nave being used for circulation and illuminated with daylight while the north and south aisles which have display units are illuminated with artificial light.

Spatial articulation affects the way daylight illuminates the gallery. Fenestration directly facing the galleries transfer more amount of daylight in Baroda museum as demanded by the volume spanning 16.6 m and 15 m high. In L.D. Museum, fenestrations on south façade facing west allows minimum amount of direct light reducing glare and dominance of daylight from the façade.

Diffused skylight gives a sense spaciousness in L.D. Museum, higher illuminance and uniform distribution gives sense of spaciousness in Baroda museum. The volume of the nave is clearly perceived as huge because of the daylight illuminating the upper volume in both the cases.

For L.D. Museum, fenestration on south façade provides opportunity for visual connection to outside. It acts as a break space in each module. Intensity of light demarcates the connection between inside and outside in the gallery.

6.2. ATMOSPHERE

Atmosphere created influences mood of the visitors which is can also be experienced as ambience of the space. Daylight is not constant while form of the building is constant. Quality of light and character of space together creates an ambience. In L.D. Museum,

dark space at eye level and bright diffused light coming from the monitor window enhance the indirect presence of sky and light in space. This characteristic of the light and space gives the sense of divinity [6].

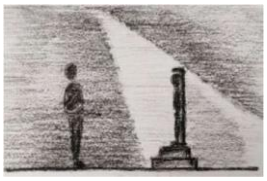
Fig. 31. Interactive light


Fig. 32. Divine ambience

Louis Claire gives classification for the ambience of the space based on light effects according to shadow rendering, contrast, and level of the light source [11]. Shadows are soft and blurred in space due to diffused light. Contrast of light level is experienced high in the gallery as the light patches of reflected daylight are visible and grey surfaces of concrete absorb light creating darkness in the space. As per Louis Claire's concept of ambience, moderate illuminance, direct lighting and negative contrast creates intimate ambience. Display units on column and direction of light contributes to the creation of a lively ambience. Light level is overall perceived as dark making atmosphere of space intimate and interactive for the visitor to object experience.

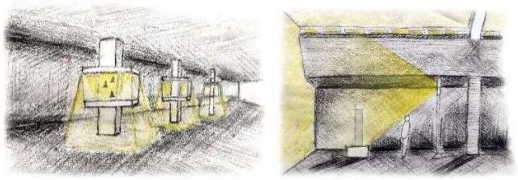
Fig. 33. Lively-Intimate ambience, L.D. Museum

Sensitive approach towards daylight design results in the light constancy in the space. The atmosphere does not significantly vary according to time of the day and throughout the year because of the integration of reflected and diffused daylight in the gallery.


Fig. 34. Magnificent-Festive ambience, Baroda Museum

For Baroda museum, high illuminance, positive contrast and multi-directional lights creates magnificent and festive ambience. Shadows of ornamentation and building elements contributes to the perception of space. Larger fenestration area and higher illuminance results into daylight variability in the museum. Daylight being the primary source of light controls the overall atmosphere of the museum. Daylight variation can be easily experienced throughout the day and year due to the form based approach of fenestration design.

6.3. VISIBILITY

Light level helps to perceive form of the space, structure and surfaces. Where bright lights enhances strong lines and planes, a dark space gives diffused character to the structure.

In L.D. Museum, light from clerestory window enhances form of the monitor and illumination from the monitor dissolves the repetitive spatial module. Perception of the monitor form is enhanced by a play of brightness and darkness. Dark background and bright exhibits creates negative contrast and improves visual comfort in the gallery. Daylight in the museum demarcates a central movement area of the gallery with a constant focus on light patches on the ceiling. Focus is the main functional aspect of artificial light in the museum. Light can provide focus either through its source or through the surfaces that it illuminates. In the case of L.D. Museum, focus is created through the illuminated surface of the ceiling by daylight.

In Baroda Museum, high illuminance and lack of light on exhibits creates positive contrast, which results into visual discomfort. Daylight illuminates the space for a general purpose, it does not enhance the perception of form or spatial character. Movement the galleries follow the rhythm of fenestration but it causes glare. Daylight emphasizes structure as fenestrations follow the structural system. Visual comfort for galleries is more in L.D. Museum because of controlled daylight in museum and strategy to design daylight enhances the spatial experience in L.D. Museum.

7. CONCLUSION

The aim of this study was to establish a relationship between spatial character and daylighting in museums. Method of visual evaluation describes the visual attributes of space and light which builds perception of a space. Observations about daylight design approach are supported by a simulation based quantitative analysis.

Analyzed case-studies show distinct attitudes to relationship of their respective form, spatiality and daylighting. Both Architectural conceptions can be said to be rooted in their own milieus. The colonial museum focuses on a rather formal outward appearance and provides a generic gallery space flooded with daylight for display. Whereas in the modernist museum design of the gallery space integrates daylighting in creation of its spatial character and experience.

In can be concluded that articulation of the spatial envelope and material technology plays major role in controlling the daylight quality in a space. Also that, application of daylight in museums has been reducing with advancement of technology and the sensitivity to use of light to create an appropriate environment for museum galleries is related to the architectural era that the institution belongs to. Though artificial lights have a functional role to play, daylight contributes in giving form to the space and in creating significant atmospheric character and visuospatial experience of museum spaces.

REFERENCES

[1] G. Böhme, "Light and Space. On the Phenomenology of Light," *Dialogue and Universalism,* pp. 5-16, 2014.

[2] T. Chandrasekaran, "Origin and Development of Museums in India," *Shanlax International Journal of Arts, Science & Humanities,* pp. 33-38, 2017.

[3] C. V. Fontenelle, "The importance of lighting to the experience of architecture," December 2008.

[4] U. Klarén, "Perceptual spatial analysis of colour and light," The Perception Studio / Konstfack–Univ. College of Arts, Crafts and Design 2010-2011, Stockholm, 2011.

[5] S. E. Rasmussen, Experiencing Architecture, Cambridge: M. I. T. Press, Massachusetts Institute of Technology, 1962.

[6] M. S. Millet, Light Revealing Architecture, Van Nostrand Reinhold, 1996.

[7] K. F. A. U. K. Harald Arnkil, "Colour and Light, Concepts and confusions," Aalto University Publication Series, Espoo, 2012.

[8] M. B. Ulrika Wänström Lindh, "Light Distribution and Perceived Spaciousness: Light Patterns in Scale Models," *Sustainability,* 2021.

[9] Y. M. H. S. M. R. A. W. Fatma Fathy, "Conceptual framework for daylighting and facade design in museums and exhibition spaces," *Solar Energy ,* vol. 204, pp. 673-682, 2020.

[10] Z. T. K. G. T. G. S. F. L. Aslıhan Çevik, "Perception of Light in Museum Environments: Comparison between Real-Life and Virtual Visual Experiences," *Sustainability,* 2022.

[11] A.-Z. Skarlatou, *Light Effects in the Design Process,* London, 2010.