03.31.2025 JOURNAL OF

Env. Management & Construction Res. (JEMCR) Vol. 7 No. 4

EXPLORING THE IMPACT OF DAYLIGHT STRATEGIES: A CASE STUDY OF YANKARI MUSEUM, BAUCHI-NIGERIA

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DOI Link: https://doi.org/10.70382/bejemcr.v7i4.007

ABSTRACT

The primary function of museum is preservation and display of museum collections for educational, entertainment and research purposes. However, these could only be achieved through careful use of daylight for preservation and display of the artifacts which will reduce use of artificial lighting and energy consumption in the gallery. Therefore, it is very important to integrate passive techniques and their application in contemporary design and construction of museum galleries. Daylight strategies is specifically known for providing natural and diffused methods of attaining visual light level into the buildings. the study is based on data obtained through computer

Introduction

Daylighting has remained the primary means of lighting to all types of building until the early twentieth century, when for various reasons, greater efficiency in the development of electric sources, the primary role of daylighting was beginning to be questioned (Chrysavgi, 2017). Daylighting characteristic high color rendering, cannot be replaced by artificial means. Because of its continuous spectrum, illumination from natural light provides unbiased color

aided daylight simulation by Design Builder version (6.1.0.006) software using radiance for calculations and real weather data for Bauchi Yankari. A physical observation and survey on the artifacts were conducted as sensitive artifacts may be subjected to damage cause by light exposure. Various condition and state of artifacts in relation to intensity of daylight fenestration into the gallery and on the surface of the artifacts using Benetech digital lux metre GM1020 version in Yankari museum were studied.

Keywords: Daylighting, Artifacts, Museum daylight, Techniques.

Registration. Although of the variations of daylight, the human eye can adapt to the changes and maintain an accurate perception of the physical properties of the object. Moreover, sudden daylighting enables the visitor to observe them as close to the lighting conditions as those under which they were created especially in paintings, natural light can reveal more on the artist's palette and technique without altering the colour of the artwork (Chrysavgi, 2017).

LITERATURE REVIEW

The history of architecture is synonymous with the history of the window and of daylighting from the initial crude openings, allowing in light and air, heat and cold, the window was the vehicle for the introduction of daylight into buildings. Ajmat et al. (2011), opined that the light to which museum collections are exposed is made up of three parts: ultraviolet (UV) radiation at one end of the spectrum, visible light in the middle and infrared radiation at the other end. A common misconception is that eliminating UV light solves the problem of deterioration. But all light, wherever it falls on the spectrum, is energy. And it is energy that drives the chemical reactions that result in damage to objects from fading. High-energy UV light falls outside the range of human vision and so is not necessary for viewing a museum exhibit. At the

other end of the spectrum is infrared light, which produces heat damage from infrared light.

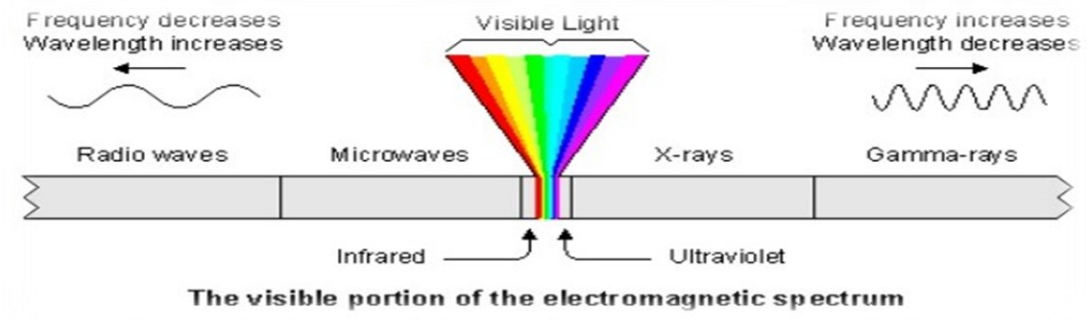

Figure 1: Electromagnetic spectrum
Source: (Srivastava, 2015).

Level, (2017) the authority on sustainable buildings states that daylight inside a building can be classified into three sources: Direct sunlight provides both light and solar gain. If the sky is overcast, solar gain is reduced but the sky dome continues to be the source of daylight.

External reflection comes from light reflecting from ground surfaces, adjacent buildings, wide window sills and light shelves. Excessive reflectance may cause glare and should be avoided. Internal reflection comes from light reflecting from the internal walls, ceiling and floor. High reflectance surfaces such as smooth or gloss surfaces, light-coloured finishes and mirrors reflect light around the room, increasing penetration and also reducing extremes in brightness contrast.

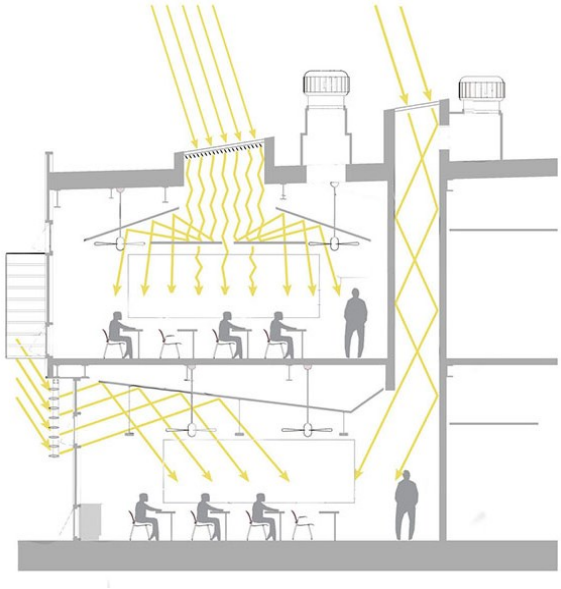

Figure 2: Daylight systems.Source: (Paula, 2018)

Effects of Daylighting on museum gallery

There are Several factors that contribute towards light damaging effects on the artifacts: from the materials which objects are made, the type and intensity of light they are exposed to and the duration of the exposure. Especially sensitive to light are objects made of organic material documents and letters, photographs, works of art on paper, textiles, clothing and accessories (Chrysavgi, 2017). The result can be irreparable damage to museum artefacts, damage that is cumulative over the life of the objects and frequently irreversible. Use diffused light rather than direct sunlight, which requires careful placement and sizing of windows. Moreover, avoid over-glazing which may cause glare and heat gain in during hot season and heat loss in dry season.

Table 1. Classification of materials according to responsiveness to visible light. (Based on data from: Control of Damage to Museum Objects by Optical Radiation International Commission on Illuminance (CIE).

	Material categories	Max. light exposure	Time of exposure	Damages
High sensitive	Object completely composed of highly light-responsive materials; works of art on paper, prints, books, letters	50 lux. Up to 150.000lx/y (50 lux x 60h x 50 weeks)	3 months	Chalking of oil paints with photosensitizing pigments (zinc white,). Yellowing of pale woods.
Moderate sensitive	Object with fugitive materials; oil painting on canvas, feathers, wood, bones, ivory, wax	50 lux. Up to 150.000lx/y (50 lux x 60h x 50 weeks)	6 months	Wood turns grey, erodes. Cracking of most plastics, resins, varnishes, rubber. Chalking of most indoor and artists' paints, bone.
Low sensitive	Object from durable materials; Plastics and wood	150-200 lux. Up to 600.000 lx/y	9 months	Cracking, chalking of plastics, rubbers, paints that contain UV stabilizers.
Non-sensitive	metals, stones, glass.	300lux. (Over this limit causes difficulties for eye adaptation and heat)	unlimited	Inorganic materials: metals, stone, ceramics, glass.

Source: (International Commission on Illuminance CIE 2022).

MATERIAL AND METHOD

The relevant data were obtained through visual survey and case study approach, given that the study is evaluative in nature. A development of model museum gallery through which computer simulations were carried out using Design builder software with reference to daylight. After all, the results were judiciously analysed and display in various tables, charts and graphs through which discussion of findings and conclusions of the result were ascertained and determined the level of expected action enhancement. Visual Survey is a method of data collection that involves physical observation and study of the building. The visual appearance of the buildings and the daylight elements were guided by literature review guidelines. Case study approach involves visitation to yankari museum as a case study was carried out and data were collected. This includes, the floor plans, window sizes, types of collection in the museum. Readings from illuminance meter were also recorded for interior daylight on artifacts for highest sunshine period of the day.

The Museum is located within yankari games reserve in south-central part of Bauchi state which covers an area of about 2,244.10km^2 and is home to several wide variety of flora and fauna. The museum was declared open in 1985 as a museum of natural history where plants, animals and archeological artifacts are being displayed. It houses trophies wildlife parts such as bones, skins, elephants' tusk, horns and full mounts of some wildlife species. The structure which is located within tropical savannah was constructed with concrete and sand screed blocks as shown below. It was renovated in 2011 which was the last major construction project in the museum.

Figure 3: Yankari Museum

Figure 4: Main entrance to Yankari Museum

Source: Auto's field work (2023)

The museum which serves as educational and conservation centre is strategically located within the built-up areas in the game reserve for easy accessibility to tourist and other visitors. The facility landscape is dominated by soft landscape and few hard landscaping elements of walkways and access roads.

The galleries consist of the main gallery, flora and fauna gallery which on the time of visits, only the main gallery was open for visitors. Conference hall of 100-seater capacity and offices serves as supporting facilities to the museum.

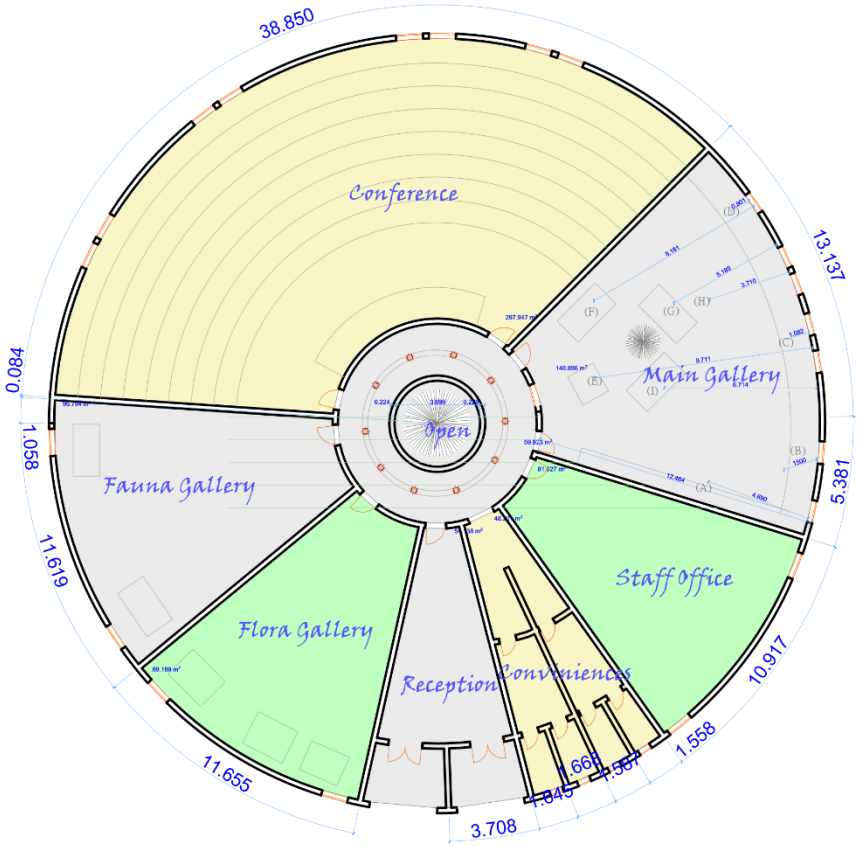

Figure 5: Floor plan of Yankari Museum.
Source: Author's field work, (2023)

The building which is in circular form called "architectural doughnut" maximise use of daylight. However, the openings significantly allow much daylight into the gallery for museum design where much emphasis is place in

daylight control. Evidently the window design is alluminium casement with light tinted glass material which intend to serve as the only shading device.

Measured illuminance level on artifacts at Yankari Museum Gallery

The daylight level in the gallery was recorded using Benetech digital lux metre GM1020 version at 850mm working plane on a sunny day (1-3pm). It shows level of daylight distribution on the surface of the artifacts by considering the distance of the object from fenestration area.

Figure 6: Illuminance metre

Architects and lighting consultants use this to test light levels in buildings, offices, workshops and production areas. Light meter GM1020 as shown in figure 3 was used to measure the actual amount of daylight falling directly on the artifacts in existing museum gallery spaces were analysed, and average of 3-4 readings were taken at the respective work plane during the sunny hour of the day (1-3:00pm).

Table 2: Artifact and daylight condition of Yankari Museum Gallery

	Collections	Categories	Distance from light source. In (m)	Range of light level readings in Lux.	Maximum light level CIE
E	Ancient cattle	Non sensitive	6.0	41	Above 300lux
I	Turtle shell	Moderate sensitive	2.0	51	50lux
F	Iron ore	Non sensitive	4.6	53	Above 300lux
H	Pieces of pottery	Non sensitive	9.0	57	Above 300lux
G	Grinding stone	Non sensitive	7.0	60	Above 300lux
A	Elephant carcass	Moderate sensitive	1.7	61	50lux
B	Hippopotamus skull	Moderate sensitive	1.5	273	50lux
C	Tuban or Wheel trap	High sensitive	0.6	295	50lux
D	Crocodile skin	High sensitive	2.3	356	50lux

Source: Authors field work (2023)

SIMULATION STUDIES FOR YANKARI MUSEUM

The model base case was produced in Graphisoft Archicad and Autodesk Revit and exported to DesignBuilder for simulation analysis. The software used to analysed the daylight condition in the existing museum to further investigate how they affects the objects. The results are recorded to score the extent to which artifacts are affected over period of time.

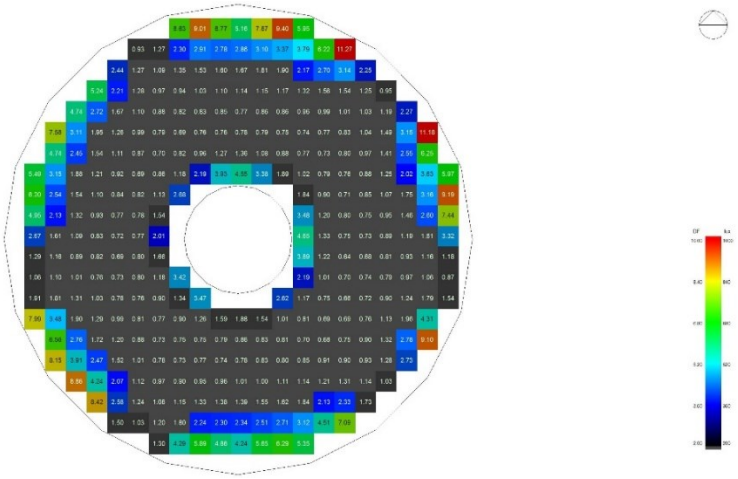

Figure 7: Lux value and daylight factor

Source: (Authors field work 2024)

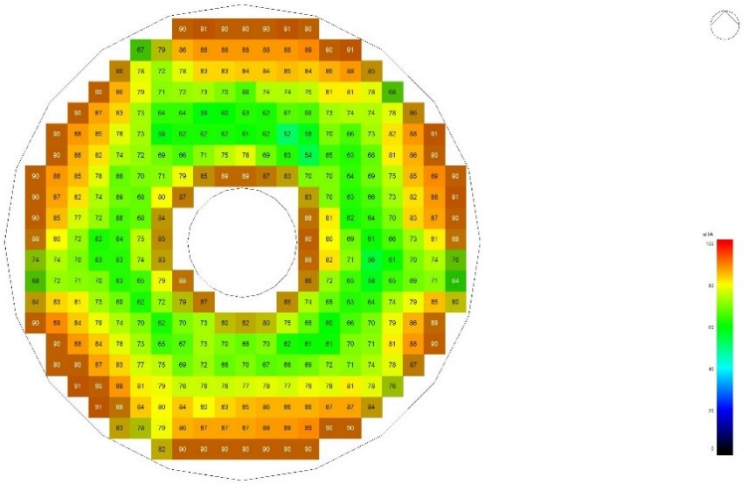

Figure 8: Spatial daylight autonomies
Source: (Authors field work 2023)

DISCUSSIONS AND FINDINGS

Daylight factor (DF) analysis indicates that from 325 sensor points only 30% of the illuminance sensor points have a daylight factor of 2% or higher. If the sensors are evenly distributed across all occupied spaces for critical visual tasks. The investigated lighting zone does not qualify for CIE and LEED standard. However, the interior shows the lux value of different lighting zones of the internal space with the highest value of 1000lux and lowest average of 64lux as seen in fig. 8. the values exceed the permissible annual daylight exposure limit. The major challenge is the high illuminance intensity value been displayed at North-South of the building. Spatial daylight autonomies for all sensor lies between 56%-91%. Measured illuminance indicates 356lux as the highest and 41lux lowest daylight level on the surface of the artifacts

CONCLUSION AND RECOMMENDATION

The literature review and case study of planning and designing of the selected building within the hot dry climatic zone of Nigeria reveals that the impact of

daylight on the artifacts is not mostly taken into considerations. Moreover, during the night and early morning period the buildings are moderately cool and store cold air. During the mid-day, excessive sunlight strikes the building, and hot air rise up the airflow from the galleries which affects the quality of the artifacts. During the noon period, all parts of the walls, floors, and roofs get warmer and the cool air spills out. Application of passive techniques like shading devices could control the effects optimally. The study explores various strategies that could be used to achieve natural and diffused lighting in to museum and reduce its effects on the artifacts. Therefore, in a contemporary architecture, it is very essential for architects, engineers, and other professionals to integrate passive techniques in contemporary designs and constructions of museums which will be more responsive to the collections and the environment.

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