Assessment of Daylighting Designs in the Selected Museums of South-West Nigeria: A Focus on the Integrated Relevant Energy Efficiency Features

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Abstract: An examination of the integrated relevant energy efficiency features is emergent to proffer amicable solutions into some tropical buildings and energy issues. This would go a long way to determine the registered thermal comfort levels enjoyable by the users, occupants and dwellers of such buildings. In this regard, great accountability is required on the part of the stakeholders, especially the Architect-designers. This study investigated the daylighting features engaged in the selected museums of South-western states in Nigeria. The integration of natural daylighting into museums spaces is a major factor in determining the positioning and sizing of fenestrations to the interior spaces of most buildings. Especially in Museum building designs where the artefacts are supposedly not to be exposed to the direct rays of the sun. The effects of daylighting exposure to the museum artefacts depends greatly on the length of exposure to light rays and object tolerance. The aim of this project is to carry out an assessment of daylighting designs in the Selected Museums of South-West Nigeria in order to integrate relevant energy efficiency features into the architectural designs. The study methodology engaged questionnaires, interview and literature reviews in order to have an understanding of the daylighting features integrated into Museum buildings. It also examined the relevant energy-design features for integrating daylighting strategies into the Museum designs. Questionnaires were administered and analysed using Statistical Package for Social Science (SPSS) through descriptive analysis of the data. The analysis showed that there are parametric-energy design indices in the existing architectural designs that are applicable in forms, spaces, materials, techniques, installation and strategies to museums in the tropical climatic regions. The analysis further showed that the use of domes, clerestory windows, atriums, light tubes and anti-solar glass/windows were considered to be most adequate daylighting features sufficient for daylighting designs and energy efficiency optimization. This study developed an architectural design model of a museum as a canonized exemplar that explores various strategies and techniques on how daylighting can be achieved in the museum spaces. It finally recommended an architectural model design specific to all tropical building species in a holistic form and spaces, and planning. These would enable a high-level patronage and optimization for entrepreneurial benefits within the confine of museums and other culture-related buildings in the tropical climate.

Keyword: Assessment; Daylighting-systems; Energy Efficiency Features; Museums; Relevant-integrated;

1.0 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. The integration of natural daylighting into museums spaces is a major factor in determining the positioning and sizing of fenestrations to the interior spaces of most buildings. Especially in Museum building designs where the artefacts are supposedly not to be exposed to the direct rays of the sun. The effects of daylighting exposure to the museum artefacts depends greatly on the length of exposure to light rays and object tolerance. The daylighting, especially in the tropical climate is expedient to foster so activities during the broad day light. But, to be effective and non-hazardous, there is a great need to control the penetration from the glare, insolation and extreme heat which may come from the direct rays of sunlight.

Although, lighting plays essential function in appreciation of space and objects especially in exhibition areas and museums spaces. It is an essential strategy for achieving energy efficiency and visual upmost satisfaction. It gives proper supply of lighting for appropriate colour rendering and has a quality which gives appropriate human responses to visual objects displayed. It also brings the experience of feeling of joy and brightness which gives a tremendous influence on viewers [1]. Lighting used in an exhibition area is a critical factor in the display of an artwork. Usage of gallery lighting differs based on the type of the building size or layout, exhibition spaces and the artworks to be displayed. Also the lighting strategy to be used for two-dimensional objects will differ from three-dimensional objects [2]. Lighting is a main design component of the exhibition space that enables the viewers to appreciate shape, shading, frame, space and surfaces within the exhibition hall. The lighting inside a space has impacts on the psychology of the audience and compliments the style of the space. It has the ability to instigate states of mind and feelings in the museum audience in this manner giving the viewer's memorable experiences. According to Arthur van der Zaag [3] various lighting strategies are based on the type and nature of the materials sensitivity to lights. Proper lighting strategies will give the viewer an experience of both the physiological, sociological and psychological influence perceived from the artworks.

Daylighting is the controlled admittance of direct sunlight or nature light into the building and through adequate provision of adequate direct link to the dynamic and perpetually evolving patterns of outdoor illumination, daylighting can help in creating a visually stimulating and productive environment for users while maximizing visual comfort and reducing energy usage. Creative daylighting strategies can be employed to tackle the need for constant dependence on artificial lighting levels. The influence of utilization of both daylighting and artificial lighting on the artefacts and viewers experience needs to be adequately considered in order to achieve upmost lighting level in the museum. Improper and ineffective utilization of daylighting strategies in the museum has led to the total dependence on the artificial lighting system leading to the spike and increase in the amount of energy consumed in the museum facilities. This energy consumption can be effectively reduced through the proper utilization of daylighting strategies in the museum spaces.

2.0 LITERATURE REVIEW

2.1 Daylighting in Tropical Museums Buildings

The utilization of daylight in the exhibition space are ought to consider the idea of the object in plain view, the induction of heat alongside intemperate direct ray beams, the right situating of wall fenestrations or skylight window, the utilization of filters to stay away from unreasonable permission of sunlight, and the introduction of other lighting for night viewing and shady or cloudy days. When sunlight and artificial light are blended, their beams ought to be completely mixed before they fall on an exhibit. This likewise implies the spatial dissemination of the two sorts of light should be considered [4]. According to Oksanen and Norvasu, [5] there are numerous sorts of radiation that are conceivably hurtful to materials utilized in artworks. Hence, the light exposure breaking points of these materials must be considered in lighting strategies. As stated by Alago [6] that the quality and illumination level of lighting for the audience comfort in the exhibition spaces will determine the success or failure of the museum design. Having a firm and appropriate control of the utilization of various variation of lighting in the museum will give the ability to attract the audience interest to the display object of arts.

Daylighting can be utilized to an incredible effect in order to make any building design enliven [7]. Daylight always changes and frequently is fused into the interactive spaces. A serious consideration must be given to the daylight impact in order to have a measurement of the sunlight that would be allowed to infiltrate the museum interior. Analysing factors such as; glare, space acclimation, reflection, solar rays must be done effectively [8]. The measure of sunlight reaching the ground fluctuates with the area, location, latitude, atmosphere, air quality and intensity of the sunlight. The sun discharges a power motion up to 63MW with close to 134Kilolux achieves the world's external air normally called sunlight. The International Commission on Illumination categorized the sky atmosphere into the clear sky and overcast sky. However, tropical region atmosphere has an additional sky between the clear and overcast skies called cloudy sky. These cloudy sky consist of moist but in spite of its predominance, the illumination level of the open air in the tropics reaches between 10Kilolux to more than 20Kilolux [9].

Tropical region buildings are affected by various variables such as; climate, social, monetary and innovative variables. Due to this region high force of sunlight radiation, the impacts of solar gains are especially considered in the structures planning. In this region, the scope of thermal consideration will need to be incorporated with the usage of daylighting which will influence the structure geometry. The impacts of solar radiation, heat gain, glare and materials deterioration are major issues related with daylighting in the tropical region. Taking care of these issues requires cautious thought of climatic conditions, solar radiation and comprehension of the luminous conditions affecting the designing for daylighting in the tropics [8].

Therefore, the appropriate incorporation of sunlight elements in lighting design needs to be accomplished in order to make the museum encounter intuitive and pleasurable. Sunlight has a significant impact of adding ambiance to spaces but it also has a negative effect on the artefacts because of the high light yield and high centralization of ultraviolet rays. These rays are harmful to the artefacts and materials when exposure to light. These therefore influence how daylight can be utilized in the museum space [10].

2.2 Daylighting Design Strategies

Daylighting strategies were classified according to Ander [11] into two namely top-lighting and side-lighting. The side-lighting makes use of the building wall perimeter to admit daylight into the interior spaces. It is considered as quite an advantageous strategy in building through its ability to give various perspective views and also provides various alternatives for ventilation. It possesses an attribute of having a solid directionality light which reduces as the distance from the opening increases. However, the high probability of it to cause glare is a dis-favourable fixture as the enlightening territory is in the field of perspectives and the high light proportions existing between the openings and the encompassing surfaces [12]. Top-lighting however, utilizes the upper part of the building elements including the rooftops, skylights and any other components around the ceiling line as shown in figure 1. The adaptability of arranging the layout, geometry and orientation of openings to the lighting needs of various spaces gives top-lighting a significant advantage as it is not also restricted or constrained to wall orientation like side-lighting.

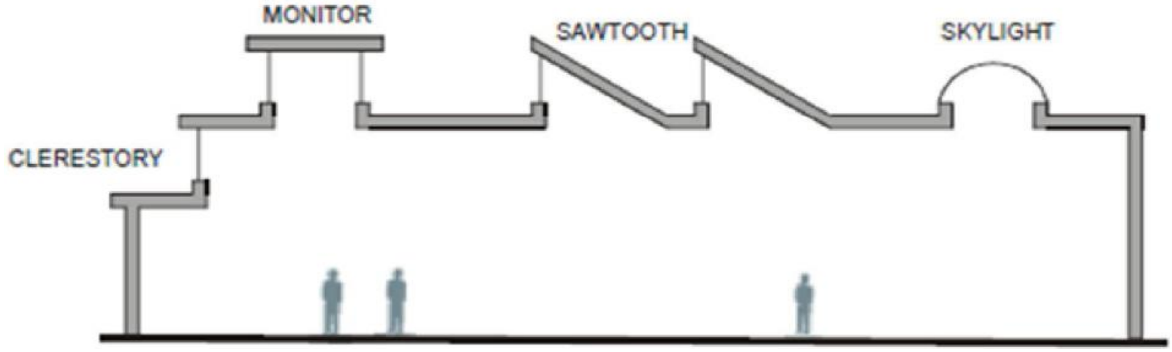

Fig 1a: *Clerestory, Monitor, Sawtooth, and Skylight*

Fig 1b: Monitor Side-lighting

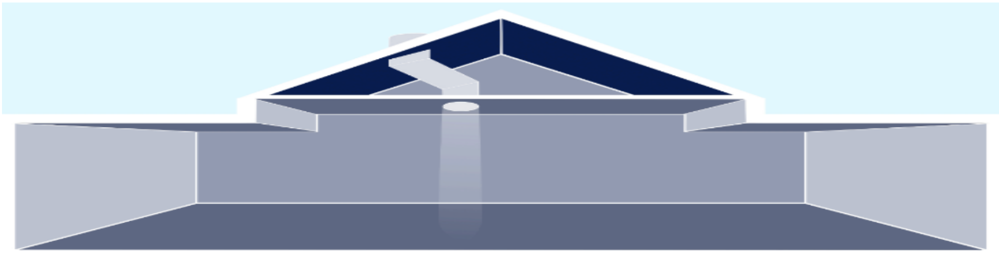

Fig 1c: light tubes Top-lighting

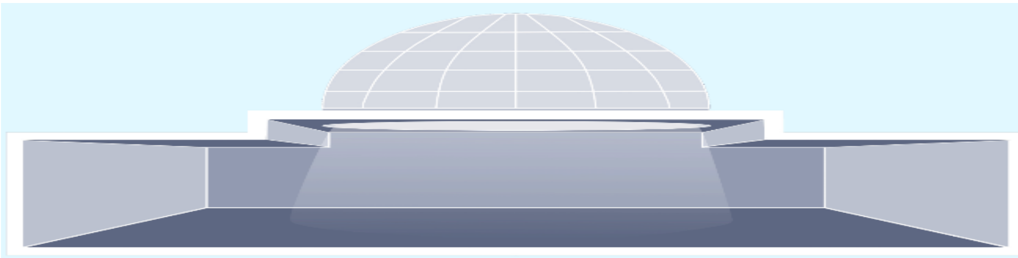

Fig 1d: Dome or Skylighting

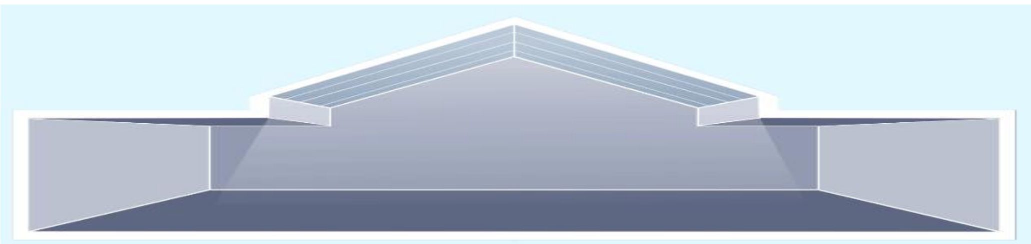

Fig 1f: Roof-Top lighting

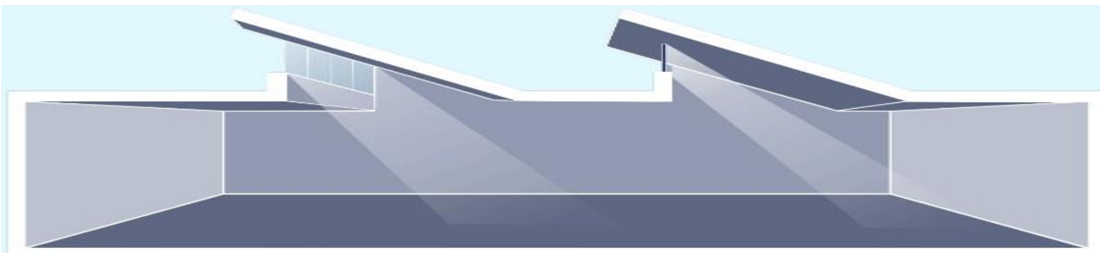

Fig 1g: Sawtooth-Lighting

Figure 1: Various top-lighting strategies [12]

Alrubaih et al.[12] expressed that although top-lighting is vital in the reduction of electric vitality utilized in artificial lighting but the potential heat gains from this lighting strategy ought to be inspected closely, especially in structures located around the tropical regions with low-latitude, hot and humid atmospheres as various strategies are shown in figure 2.

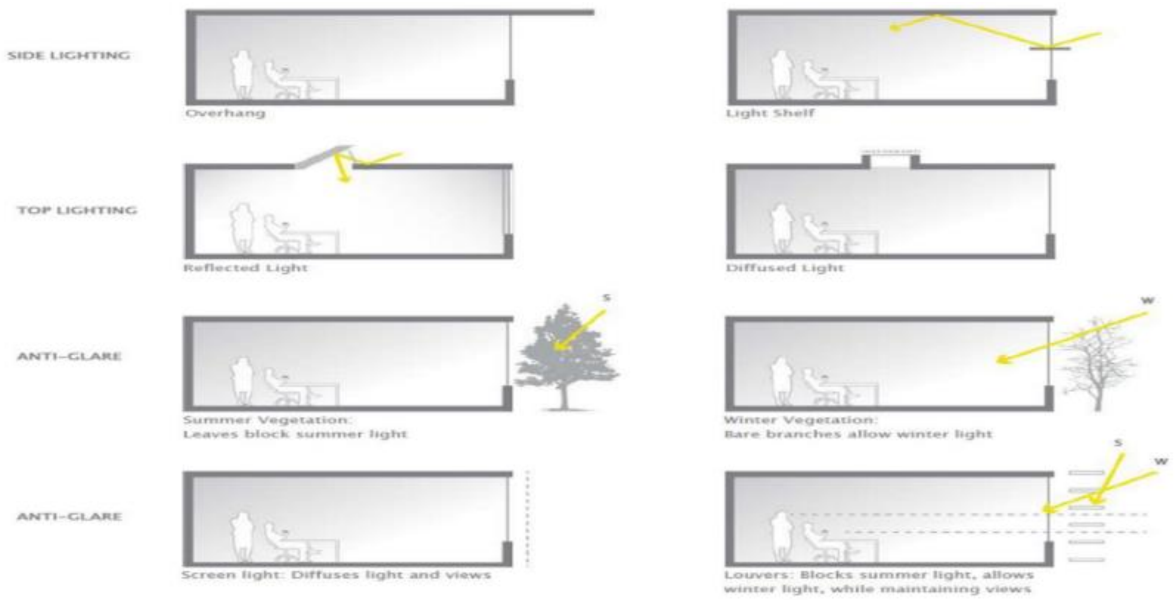

Figure 2: Daylighting strategies [13]

Light pipes system is a roof lighting technique that involves the use of reflective tubes to transfer light to a specific space in a building as seen in figure 3. It is seen as a light fitting that uses sunlight as its source of light. This is also used as daylighting strategies for allowing natural lights into interior spaces.

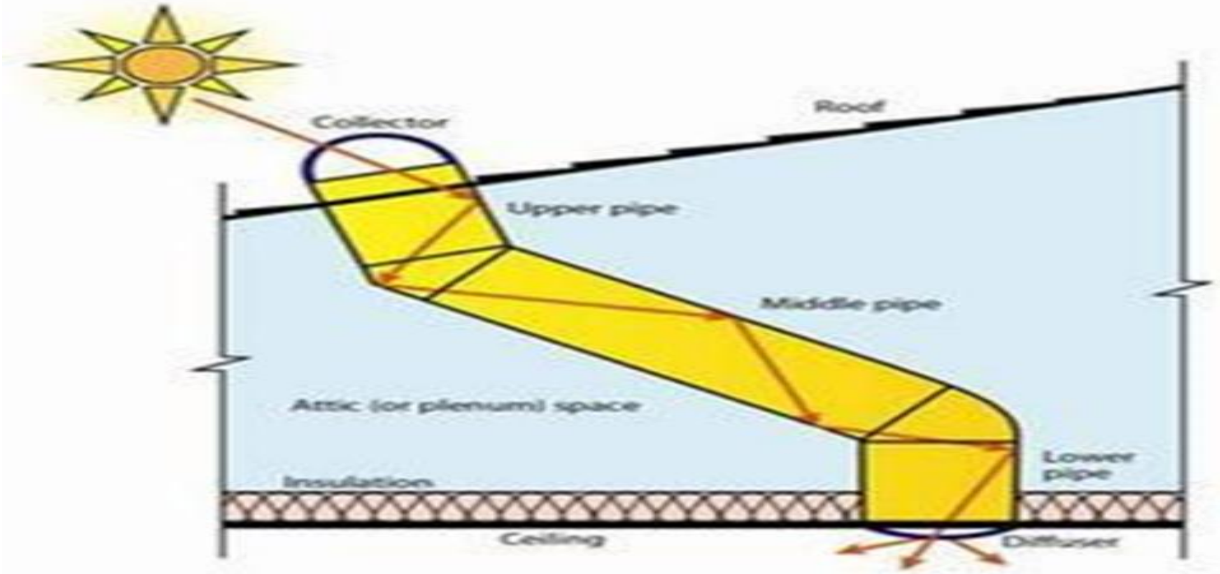

Figure 3: Illustration of light reflection inside a light pipe [14]

2.3 Thermal Comfort in Museum

Thermal comfort can be defined as the state of mind expressing satisfaction with the thermal environment [15]. The thermal comfort quality of an indoor spaces has a great impact on the satisfaction of the users with a building [16]. The numbers of Museum visitors vary depending on the time and season. Each of these particular times requires the achievement of thermal comfort to make it comfortable for the visitors. According to Frontczark, Schiavon, Goins, Arens, Zhang, Wargochi [17], it was discovered that thermal comfort is ranked the greater significance when compared to acoustic and visual comfort during their review of indoor environment conditions. However, in the consideration of this discovery in a museum, the biggest effects of satisfaction to the visitors are; the illumination, exhibition strategies, easy visualization of exhibits and the displayed contents [18].

Achieving natural ventilation involves the utilization of fenestrations and appropriate building orientation towards the wind direction to achieved a proper exchange of stack and fresh air. Issues like the speed control of air inlet, environment pollutants levels and air temperature and humidity must be considered in order to achieve the best utilization of natural ventilation in the museum. While artificial ventilation deals with achieving air movement within a space through the utilization of mechanical devices such as; air filter, conditioning and air intake fans. The climatic requirement of the space involving the humidifying or dehumidifying, the cooling or heating of the spaces are filtered through the air conditioning within the museum by the ventilation plants to suit the required need. The pre-determined level of temperature and humidity appropriate for the preservation of the objects of arts and the comfort of the audience are taken into consideration in the air conditioning system to ensure that the right amount of fresh air is evenly diffused over the whole area.

HVAC [heating, ventilation and air-conditioning] system serves as a vital function in the preservation of cultural heritage and artefacts through controlling of the surrounding conditions. The flow of air allowed into the various exhibitions and supporting spaces in the museum is controlled by this system. Through this control, the quality of indoor air can be maintained at an acceptable level notwithstanding when the exhibition spaces are swarmed and also enable achieving energy saving with the building. Transfer of water vapour and condensation is prevented by the HVAC system in the various spaces while humidity is likewise controlled [19]. According to Bellia, Capozzoli, Mazzei, & Minichiello [20], museums HVAC system are required to keep cooling and heating, humidification, filtration, dehumidification maintained at a strategic distance from the artifacts to prevent harm and risks.

2.4 Energy Efficiency Features

2.4.1 Lighting

Natural and artificial lighting system will be used in the museum to achieve adequate lighting strategies to create a functional environment. Natural light will be introduced within the spaces, office space and workspace of the museum. Exhibition spaces will also be lit through both lighting strategies. However, the solar radiation that comes with the sun rays will be considered and treated in order not to create a harmful effect to the artefacts displayed. Daylighting will be allowed into various spaces through strategically placing of windows, atriums and other openings in order to receive adequate sunlight into each space hence enhancing an energy efficiency structure. Shading devices will also be installed to control solar gain.

Artificial lighting is likewise important to the museum as it can be used to communicate with the visitors and improve their experience of the museum. It will be used to supplement the natural lights introduced into the spaces in order to boast visibility in places where glares are avoided. Various artificial lighting fixtures will be installed either directly or indirectly in the exhibition spaces to help the illumination of the space.

Motion detectors and light sensors will be installed to control energy consumption level in the building. Various factors like the room height, color temperature, light distribution and directionality, glare limitation, illumination level and sensitivity to lights will affects the choice of lighting strategies to be used as shown in figure 4. The use of dimmers and controllers will be used to achieve the preferable tone and mood as indicated n figure 5.

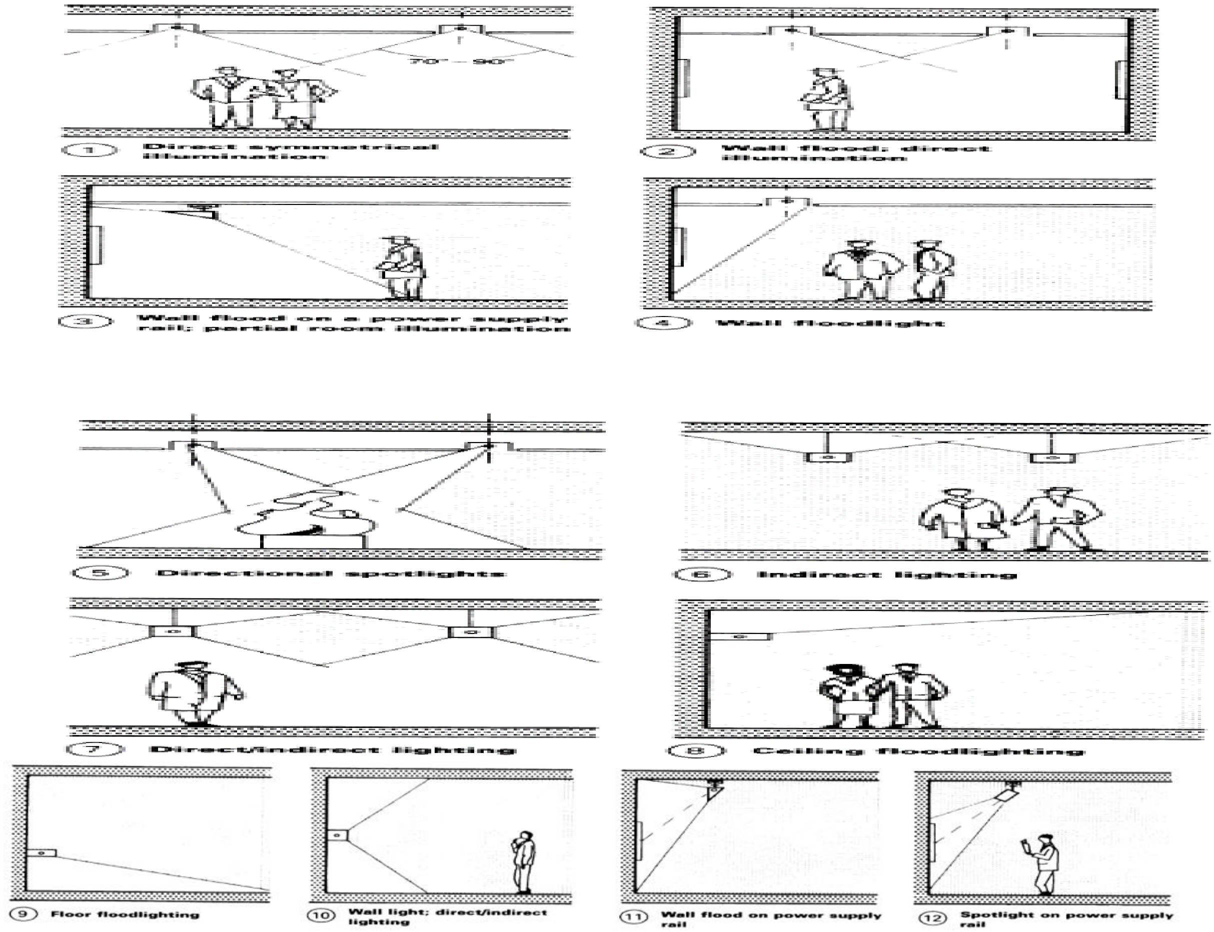

Figure 4: Various artificial lighting style for exhibition spaces [21]

lighting type		flood lighting	spotlights	uplights	downlights	grid lighting: square grids	grid lighting: rectangular grids
A	general purpose lamp 60–200 W		○		○		
PAR, R	parabolic reflector lamp reflector lamp 60–300 W		○		○		
QT	halogen filament lamp 75–250 W	○	○	○	○		
QT–DE	halogen filament lamp, sockets both sides 100–500 W	○		○			
QT–LV	low-voltage halogen lamp 20–100 W		○		○		
QR–LV	low-voltage halogen reflector lamp 20–100 W		○		○		
T	fluorescent lamp 18–58 W	○		○		○	○
TC TC–D TC–L	compact fluorescent lamp 7–55 W	○	○	○	○	○	○
HME	mercury vapour lamp 50–400 W				○		
HSE/ HST	sodium vapour lamp 50–250 W				○		
HIT HIT-DE	halogen metal vapour lamp 35–250 W	○	○	○	○		

Figure 5: Allocation of artificial light types [21]

2.4.2 Anti-Solar Reflective Glass

The introduction of natural lighting into the exhibition areas requires adequate consideration in order to prevent the impact of solar rays and radiation emerging from the sunrays and it can also be allowed through diverse means either through; atrium, courtyard or via glass curtain walls. However, the creation of anti-solar glass which allows light to pass through it but deflect solar radiation and solar heats off it gives the benefits of introducing more natural lights into the museum spaces without the harmful effects of solar rays on the artefacts. This hereby creates a lesser utilization of artificial lighting system in the spaces and in turn reduces the energy usage of the building. In addition, the anti-solar glasses can be used as an energy saving devices to create alternative power supply through acting as a photovoltaic panel as shown in figure 6.

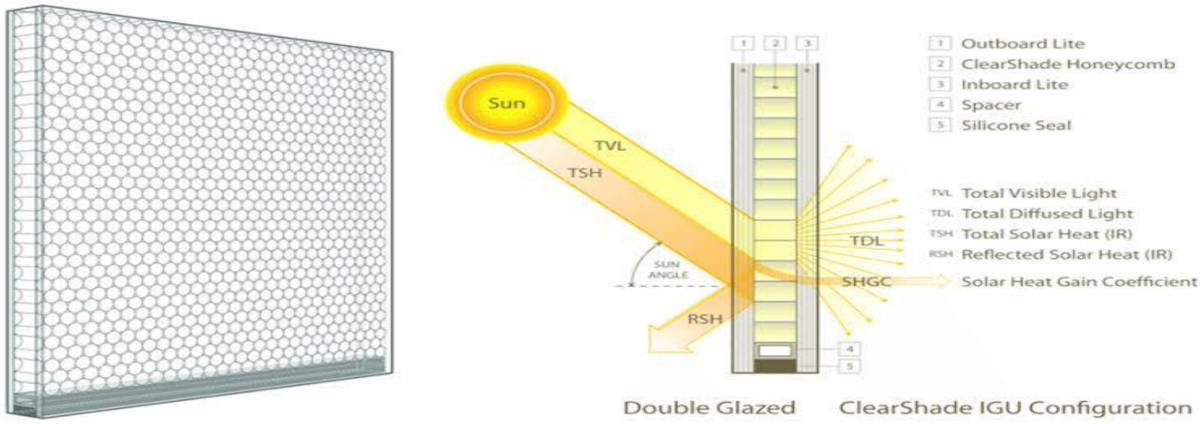

Figure 6: picture showing the innovation of solar radiation penetration prevention [22]

3.0 METHODOLOGY

This research was carried out using both qualitative and quantitative research methods. The qualitative method involved the in-depth review of relevant literature to identify the daylighting strategies to be employed in museum buildings, while the quantitative method involved the distribution of structured questionnaires to users of the selected museums centres in South-western region of Nigeria, to investigate the integration of the identified daylighting strategies implemented in the centres. According to NCMM [23], they are currently 12 museums centres in the south-western region of Nigeria as shown in table 1.

Table 1 List of Museum in South-western Region of Nigeria

S/N	LIST OF MUSEUMS IN SOUTHWEST REGION	LOCATION	CURATOR
1	National Museum of Unity, Ibadan	Alesinloye Area, P.M.B. 5524, Ibadan, Oyo State	Amos E. Olorunipa
2	National Museum, Abeokuta	Baptist Girls College, Idi-aba, P.M.B. 2004 Abeokuta, Ogun State	Gabriel Oko
3	National Museum, Akure	Opposite Post Office, Oba Adeside Road, P.M.B 444, Akure, Ondo	Ogumola Dada Nathaniel
4	National Museum, Esie	P.M.B. 301, Esie, Kwara State	Mopelola Mowunmi (Mrs)
5	National Museum, ICT Centre, Oko, Surulere	P.O.Box 1706, Oko, Ogbomosho, Oyo State.	Fatoke O. Solomon
6	National Museum, Ile-Ife	Enuwa Square, P.M.B. 5515, Enuwa Ile-Ife, Osun State	Ogundele J. O. (Mr)
7	National Museum, Ilorin	14 Abdulkadri Road, P.M.B. 1549,GRA Ilorin, Kwara State	Bimpe Oladele (Mrs)

8	National Museum, Lagos	King George V. Road, Onikan, P.M.B. 12556, Lagos State.	Adobeye O. M (Mrs)
9	National Museum, Ogbomosho	No. 3 Museum Street, Off, Sunsun Road P. O. Box 1602, Ogbomoso, Oyo State.	Toyin M. Oke
10	National Museum, Osogbo	Ataoja's Palace, P.M.B. 4376, Osogbo, Osun State.	Fatai Adekunle.
11	National Museum, Owo	Olowo's Palace, Owo, P.M.B. 1003, Owo, Ondo State	Adeoye O. Akanni
12	National Museum, Oyo	No.1 Palace Road, Alaafin Oyo, Oyo State	Adekunle Adedimeji Sunday

Source: (NCMM, 2018)

Therefore, three Museum centres were randomly selected from the list of museums in table 1 namely; National museum of Unity. Oyo state, National Museum Onikan, Lagos state and National History Museum Ile-ife, Osun state. The distribution of the survey was carried out using the census sampling method, which involves the distribution of questionnaires to all users found within the centre as at the time of visit. This was done to attained the maximum possible number of responses as it was discovered that the highest number of visitors are only during festive period. A total number of 99 questionnaires were distributed across all three centres, but only 90 questionnaires were retrieved. The recovered questionnaires were analysed with statistical package for social science (SPSS). The result is presented using descriptive approach using tables.

4.0 RESULTS AND DISCUSSION

This section retrieved information on how daylighting features can be integrated into the Museum buildings by various daylighting strategies.

4.1 Examining the daylighting features

The relevant philosophy behind daylight strategies was presented to the respondents in order to specify their level of agreement under the linker scale of measurement. The results are presented in table 2 as follows;

Table 2: frequency and percentages of relevant daylighting strategies

S/N	How would you agree to the following?	No of respondents	Strongly Disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly Agree (%)
1	Proper lighting strategies foster effective display of artefacts	90	0 (0%)	3 (3.3%)	9 (10%)	42 (46.7%)	36 (40%)
2	Proper considerations need to be placed on the lighting strategies to stop deterioration of artefacts	90	0 (0%)	3 (3.3%)	9 (10%)	36 (40%)	42 (46.7%)
3	More natural lights should be allowed into the exhibition spaces	90	2 (2.2%)	6 (6.7%)	27 (30%)	31 (34.4%)	24 (26.7%)

4	The use of both natural light and artificial light will create better lighting conditions in the museum	90	3 (3.3%)	3 (3.3%)	6 (6.7%)	45 (50%)	33 (36.7%)
5	The illumination system is adequate enough	90	3 (3.3%)	6 (8.9%)	27 (30%)	42 (46.7%)	10 (11.1%)
6	The artificial lighting system are adequate enough for the museum	90	12 (13.3%)	32 (35.6%)	18 (20%)	16 (17.6%)	12 (13.3%)

The respondents' responses to their perception on if proper lighting strategies would foster effective display as seen in table 2 indicates 3.3% disagrees with the thought, 10% are undecided about the effect, 46.7% of the respondents agrees with it and 40% strongly agrees with the idea that proper lighting strategies will foster effective display of artefacts. The total percentage of 86.7% agreeing to the variable signifies the necessity to have a proper consideration in the lighting strategies in the exhibition spaces.

The respondent was further asked for their perception on the use of lighting strategies to prevent deterioration of artefacts to compare with the first variable, the same percentage of respondent shows similar disagreement and uncertainty with 3.3% and 10% respectively, 40% agrees and 46.7% strongly agrees. The agreement percentage at 86.7% signifies the importance of having a proper consideration on the lighting strategies in the museum.

The respondents' response to the use of more natural lights in the exhibition spaces shows, 2.2% strongly disagree, 6.7% disagree, 30% undecided, 34.4% agrees and 26.7% strongly agrees. This result signifies the need to infuse more natural lights into the space. Furthermore, the respondent view about the combination of both natural light and artificial light to create better lighting conditions indicates that 3.3% strongly disagrees, 3.3% also disagrees, 6.7% are undecided, 50% of the respondents agreed and 36.7% strongly agreed. The high percentage of agreement motivates the need combining both lighting strategies effectively for better light conditions. On their reception about the need of adequate illumination system, 3.3% strongly disagree, 8.9% disagrees, 30% are undecided, 46.7% agrees and 11.1% strongly agrees, which indicates the essential need of consideration on the illumination system for the museum. The respondents' perceptions on if using artificial lighting system only is adequate enough for the museum, 13.3% strongly disagrees, 35.6% disagrees, 20% are undecided, 17.8% agrees, 13.3% strongly agrees. This result signifies that dependence on the artificial lighting system is not adequate enough for the museum spaces.

4.2 Integrated features of daylighting system

To achieve the design of the museum integrated with efficient daylighting systems, the features of daylighting systems were presented to the respondents to determine their agreement with the usage of the features in the museum building. The respondents' perception on the integration of daylighting features into the Museum Buildings, the parametric indices area as follows in Table 3:

Table 3: frequency and percentage of daylighting features

S/N	**Daylighting Features**	**No of respondents**	**Strongly Disagree (%)**	**Disagree (%)**	**Undecided (%)**	**Agree (%)**	**Strongly Agree (%)**
1	Infusion of courtyards to allow more Daylighting	90	3 (3.3%)	9 (10%)	7 (7.8%)	38 (42.2%)	33 (36.7%)
2	Usage of anti-solar glass windows	90	0%	0%	18 (20%)	45 (50%)	27 (30%)

3	Usage of top light windows in the exhibition halls	90	12 (13.3%)	3 (3.3%)	3 (3.3%)	42 (46.7%)	30 (33.3%)
4	Minimum dependent on artificial lighting system	90	3 (3.3%)	3 (3.3%)	21 (23.3%)	30 (33.3%)	33 (36.7%
5	Usage of energy saving photovoltaic panels	90	0%	0%	17 (18.9%)	49 (54.4%)	24 (26.7%)
6	Usage of carbon dioxide sensitive lighting fixtures.	90	3 (3.3%)	3 (3.3%)	21 (23.3%)	45 (50%)	18 (20%)
7	Usage of light tubes	90	0%	12 (13.3%)	15 (16.7%)	39 (43.3%)	24 (26.7%)

The respondents' perception with the *use of courtyard spaces* in the museum to allow more daylight into the inner spaces as seen in Table 3 indicates that 3.3% strongly disagrees, 10% disagree, 7.8% shows undecided, 42.2% agrees and 36.7% strongly agrees. The result indicates the support of the respondent with the infusion of courtyards in the building to allow more integration of daylighting into buildings' interiors. The usage of *anti-solar glass windows* in order to avoid the penetration of solar radiation into the exhibition halls respondents' responses are; 0% disagree, 20% undecided, 50 % agrees with the usage and 30% strongly agree. The *disagreement* by the respondent with the usage of anti-solar glass windows signifies an unavoidable usage of the daylight energy-efficiency features. On the usage of *top light windows* in the exhibition halls to allow more natural lighting into the space shows a result of, 13.3% strongly disagree, 3.3% disagree, 3.3% undecided, 46.7% agrees and 33.3% strongly agrees with the usage of top light windows. The percentage of agreement also indicates the need of implementation in the design of the museum. The respondents' responses to the minimum dependent on artificial lighting system in the museum results has, 3.3% strongly disagree, 3.3% disagree, 23.3% undecided, 33.3% agrees and 36.7% strongly agrees to the museum having a *minimal dependence* on artificial lighting system.

The usage of energy saving *photovoltaic panels* in the museum to serve as a means for alternative energy for the museum in the absence of natural lights has respondent's perception response as, 0% disagree, 18.9% undecided, 54.4% agrees with the usage and 26.7% strongly agrees with the usage. The absence of any disagree respondents signifies the importance of the implementation of the Photovoltaic panels in the design to provide alternative artificial light source. The usage of *sensitive lighting fixtures* to achieve efficient energy control has some responses of; 3.3% of strongly disagree, 3.3% of disagree, 23.3% undecided, 50% agrees and 20% of the respondents strongly agree with the usage. The respondent's responses towards the *usage of light tubes* in the museum shows; 13.3% disagrees, 16.7% undecided, 43.3% agree and 26.7% strongly agreed with the usage of light tubes which is another type of daylight strategy.

4.3 Energy Efficiency Design Model Solutions in Museum Design

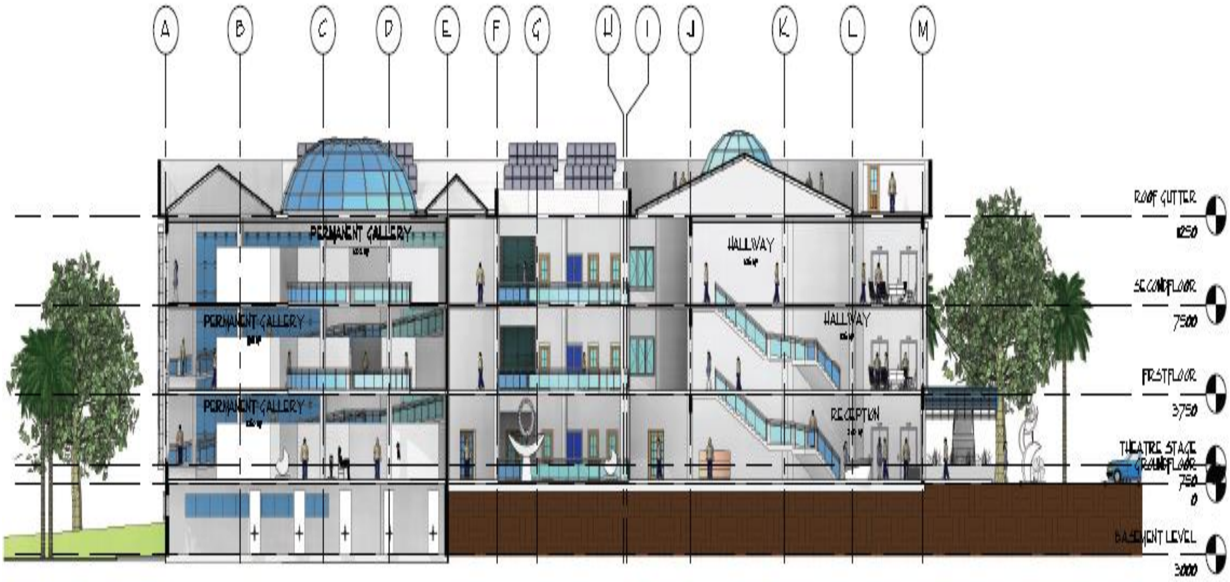

Figure 7: Section AA showing the architectural design of an Ultramodern Museum design for Oyo State

In Fig.7, the section above shows the architectural design of Ultramodern Museum design for Oyo State, Nigeria-section drawings. The upper part of the roof design contained an integrated energy-design feature; a *Dome* Structure carefully imposed on the entire Museum Structural *Spaces*. The glazed membrane allows the penetration of direct rays of sunlight into the museum interior. The strategy involved following are derivable architectural design solutions from the findings and analysis.

Figure 8: Section BB showing the photovoltaic installation and the overhang cantilever

In Fig.8, the section above is the Ultramodern Museum design for Oyo State, Nigeria. The energy efficiency features utilized are the photovoltaic panels inclined tangentially to receive the solar rays at an approximate angle of between 40-45 degrees. Furthermore, the use of light tubes into the interior spaces as an alternative to artificial lighting fixtures was also considered as shown in figure 8; this also serves as energy efficiency design features. It connects the external daylighting naturally to the interior spaces. On the internal surfaces, it has an overlay material from the chemical Noble gas element family i.e. noble/rare gases like Neon, Argon, Lithium, Beryllium and others elements in that category. These helps to transmit the daylighting in any form of required moods based on the functional needs of such spaces; for instance, the mood requires in the gallery space may be different from that of exhibition space and may also be contrary to the library. These variations may be in terms of colour hues, space textures, intensity or light pattern.

Figure 9: Elevation showing the anti-solar glass façade

In Fig 9, the elevation above showcased the relevant integrated energy features as implemented on the architectural model-design of Ultramodern Museum Building for Oyo State. The façade is a compendium of energy efficiency features derivable from the findings and analysis of the investigations made during this study. Basically, *solar shading devices and daylighting features were integrated in this architectural design. On the left wing is the cantilevered roofing system hung deliberately to hover on the porch, next to this on the elevational plane are the skin membrane of perforated honeycombed walls strategically installed to shield the semi-exterior spaces from the direct rays of light. Consequently, beneath the honeycombed screen walls are the anti-sol glazing with energy-efficient optimizable* advantages which were technologically premised around its energy properties: (i) it admits daylighting rays to penetrate through its medium (glass) to the interior functional spaces, and (ii) also absorbs the insolation or solar heat into itself and releases it to the external spaces gradually until the insolation is finally emitted to the external atmosphere. It mechanizes in this way to excludes undesirable heat away from the interior spaces to ascertain a moderate level of thermal comfort (25) for the Building users.

4.0 Recommendations and Conclusions

This study developed an architectural design model of a museum as a canonized exemplar that explores various strategies and techniques on how daylighting can be achieved in the museum spaces. It engaged various strategies extracted from the research analysis and results. It established that the use of domes, clerestory windows, atriums, light tubes and anti-solar glass/windows were considered to be most adequate daylighting features sufficient for daylighting designs and energy efficiency optimization. The model solutions in this work deliberately avoided the representation of regional (South-West-Oyo State) Cultural Motifs, artefacts and patters as normally symbolized by many Museums for ethnographical reasons. More so, it is epistemic to state clearly that the Soul of this work was delicately embedded in the Capsules of Energy Efficiency requirements. It therefore recommended an architectural model design specific to all tropical building species in a holistic form and spaces, and planning. These would enable a high-level national policy (24) on sustainable energy-efficient architectural designs capable of promoting greater users' patronage and building optimization; for entrepreneurial benefits within the confine of museums and other culture-related buildings in the tropical climate.

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