iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** IX **Month of publication:** September 2019

DOI: http://doi.org/10.22214/ijraset.2019.9132

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue IX, Sep 2019- Available at www.ijraset.com

Achieving Effective Internal Visibility through Daylighting at National War Museum Umuahia, Abia, Nigeria

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Abstract: ***The National War Museum Umuahia, Abia, Nigeria, is the only museums in Nigeria that specializes in military histories, it displays weapons and other military hardware, uniforms, wartime propaganda, and artefacts on civilian life during wartime, and decorations, among others. The museum depends heavily on artificial Light, Powered by a 3.0Kilowatt electrical generation set placed at the entrance porch of the museum because the existing daylighting technique is not functional. This paper seeks to achieve effective internal visibility by harnessing natural light through sustainable daylighting techniques and building design of the National war museum Umuahia. Interview with members of staff of the Museum was carried out to achieve a clear and concise user experience of the characteristics of the indoor lighting, case studies of two Nigerian Museums viz National war museum Umuahia, Anambra, National Museum Benin Edo state and one foreign museums; Louver Lens Museum France, were carried out also to evaluate and analyze the daylighting system in use thereby recommending suitable sustainable bespoke daylighting solutions. The predominant atmosphere and climatic element of the micro and macro ambience of the project site and relevant planning laws served as bases upon which this paper began. This paper clearly reveals that the current internal lighting techniques of the National War Museum Umuahia is not sustainable and recommends the use of automatic louver lens skylight (controlled daylight sensor) for roof light to achieve sustainable internal visibility.***
Keywords: Museum, Daylight, Daylighting, artefacts, skylight.

I. INTRODUCTION

According to Ros, (2017) War museums have been set up around the world to preserve the memory of armed conflicts and the people who fought in them. Military or Civil war, Genocide, and Holocaust museums specialize in military and civic histories. Nwaneri (2014) claimed that the national war museum Umuahia was established in 1985 by the then military council. The idea of establishing a National War Museum in Nigeria was spearheaded by Lieutenant General Theophilous Danjuma after an official visit to Yugoslavia in 1977. It was approved by the Supreme Military Council of the Lt. General Olusegun Obasanjo administration in the same year. It is the only museum in the country that deals with military hardware (Nwaneri, 2014). In Summary, the museum was established with the sense of patriotism, and aimed at celebrating and preserving the memories of our fallen heroes lined directly or indirectly to the Nigerian civil war.

Merriam-Webster, (2018) defines daylight as the light of the day, dawn, and daytime. Daylighting according to Oxford University Press (2018) is the illumination of buildings by natural light. Douglass (2014) also noted that daylighting is the controlled admission of natural light into a building to reduce electric lighting and save energy. The sun is the earth's original source of light, and 'daylighting' is the purest way to use that light. In structures, the term daylighting refers to the controlled admission of this natural light into a building (Sundolier, 2018). Ander (2016) similarly explained that a daylighting system is comprised not just of daylight apertures, such as skylights and windows, but is coupled with a daylight-responsive control system. When there is adequate ambient lighting provided from daylight alone, this system has the capability to reduce electric lighting power.

In the light of the above statement, natural light can be said to be sustainable because it has no carbon footprint and it is a free gift from nature. Although natural light is in between infrared and ultraviolet radiation, and it varies from time to time as stated above, it can be harness if carefully considered early during building design.

This paper, attempt to harness natural light to achieve effective display of artefacts, through sustainable and near zero carbon footprint daylighting design solutions.

It has been affirmed that 80 million people are without access to electricity and millions more suffer from poor service in Nigeria

(Vanguard Media Limited Nigeria, 2017). In a similar report Muanya, (2017), stated that Nigeria is second to India on the list of countries with the highest electricity access deficit with 75 million people compared to India's 263 million persons. This is also in line with The Globalist, (2018) which states that Nigeria is Africa's largest country by population (180 million), however, 52% of Nigerians lack access to electricity. The civil war museum Umuahia also lacks proper electricity supply as justified by Uguru, (2015) who also stated that the indoor gallery was not well lit as there was poor power supply. He further pointed out that the museum depends heavily on a small electricity power generation set that was supplying electricity. National civil war museum Umuahia depends heavily on 3000watt electrical generator placed at the entrance porch which emits carbon dioxide and noise pollution within the museum (Aduaka, 2018). The running cost of museum is mainly on lighting and HVAC system (Adebamowoa, et al., 2013). Hunt (2007) in line with De Chiara (2007) stated that Museum designs incorporate daylight because humans relate to nature. Striking architectural elements will be featured in this paper to aid free interaction with nature and outdoor for effective museum experience. This paper aims at achieving sustainable internal visibility at the National War Museum, Umuahia, Nigeria, through Daylighting. This is achieved by investigating daylighting and its design criteria, and evaluating common applied sustainable daylighting techniques for internal lighting system.

II. LITERATURE REVIEW

A. *Introduction to Museum and Daylighting*

Oladumiye (2014) Stated that Museums are essential institutions with such obligation as nurturing, safeguarding and handling diligently over from one generation to another artefacts or stories in history, that is, the pride of the people in relation to their cultural heritage and way of life. It is pertinent to note that the nation or its people cannot exist without the preservation of their cultural posterity of its territorial integrity. Alexander, and Porter (2007) also define a museum as an institution that cares for (conserves) a collection of artifacts and other objects of artistic, cultural, historical, or scientific importance. Many public museums make these items available for public viewing through exhibits that may be permanent or temporary. According to Geoffery (2018), museums, is an institution that preserve and interpret the material evidence of the human race, human activity, and the natural world. Having reviewed critically the above definition of museum, it can be concluded that a museum is a place for the collection and preservation of object that display the characteristics and cultural heritage of a community or a group of people. It can also be deduced from the above that museums are primarily Western in origin, but the concept of preservation of sociocultural and Eco political status has long been evident in other cultures before the formal advent of museum. For instance, in the Cross River region of West Africa, certain masks were given to a tribal elder or other responsible person for safekeeping.

Before the 1940s, daylight was the primary light source in buildings; artificial lights supplemented the natural light. In the short span of 20 years, electric lighting had transformed work places by meeting most or all of the occupants' lighting requirements. Recently, energy and environmental concerns have made daylighting a rediscovered aspect of building lighting design. (Ugochukwu., 2011). Daylighting is often integrated into a building as an architectural statement and for energy savings. However, benefits from daylighting extend beyond architecture and energy. The comforting space and connection to the environment provided to building occupants provide benefits as significant as the energy savings to building owners and managers (Edwards & Torcellini, 2002).

B. *Daylighting Design Criterial and Common Daylighting Design Solutions*

Natural Light can be used to great effect to dramatize and enliven the design of any building (De Chiara, 2007). Light Sources (2015) elucidated that since the formation of the Sun and the solar system (including our planet) about 4.5 billion years ago. Earth has been bathed with light from the Sun ever since. It can be said that the sun is our most important source of energy. Paine (2018) Define Natural light as self-generated and comes in a spectrum of colours (The visible colours of the rays we experience). From the above it is unarguable that before designing a suitable daylight system for a project, it is however noteworthy to have critical knowledge of the characteristics and properties of natural light.in line (Garris, 2014) it can credible to say that daylight is the treatment of sunlight to sustainably serve the function of a building. (Ryer, 1998) Enumerate this properties as:

1) *Design Goals and Standard:* The IEAECBCSP(2000) opined that as the building scheme is being created, daylighting design influences and/or is influenced by basic decisions about the building's shape, proportions, and apertures, as well as about the integration and the role of building systems first step, design basis would be to define lighting requirements and to establish the role daylighting can play in meeting these requirements. Similarly, Ugochukwu, (2011) recommended that the first design step to daylighting would be to define lighting requirements and to establish the role daylighting can play in meeting these requirements. It can be concluded that the required daylighting strategy and lighting minimum requirement should be clearly defined at the preliminary stage of a design.

2) *Illuminance:* is a measure of photometric flux per unit area, or visible flux density. Illuminance is typically expressed in lux (lumens per square meter) or foot-candles (lumens per square foot). (Ryer, 1998). One can also say that it is the density of a luminous flux incident on a surface and is measured in units of 'lux' (lumens/m2) or 'footcandles' (lumens/ft2).
3) *Average Daylight Factor:* This can be expressed as the area of the total light flux incident on the working Plane to the total area of the working plane. Express as a percentage of the outdoor illuminance on an horizontal plane due to an unobstructed CIE standard overcast sky (Littlefair, 2011)
4) *No Skyline:* The outline on the working plane (850mm form ground floor level, as recommended by beyond which no visible light can be seen (Brent Cross South Limited, 2017). The figure below shows the no sky line profile of an interior space.

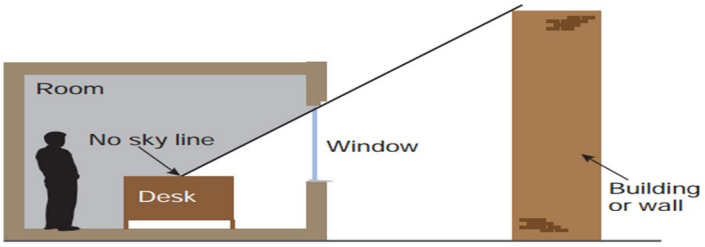


Figure 1: The no sky line shows working plane which can and cannot receives direct skyline (Littlefair, 2011)

5) *Building Orientation:* Innovative Design (2004) opined that a sustainable daylight design starts with a good orientation. The position of the sun, at a particular time of the day and year determines the daylight condition to be adopted in a building design (Ernst & Peter, 2000). Having considered the importance of proper building orientation to achieving a sustainable daylighting solution, it is unarguable to conclude with Lauren & Matthew (2014) recommendation that a simple liner building to be parallel to east-west direction for good solar and heat performance.
6) *Building Forms:* Brent Cross South Limited (2017) stated that shaping the massing to allow for greater sunlight levels to reach the communal open spaces, is the basic daylighting strategies that should be critically observed to achieve sustainable daylighting. The building foothprint with much shadow area represent the with poor natural dayligt access (Littlefair, 2011). One can conclude inline with CPWGS (2002) that the core is best used for services.
7) *Building Shell:* The Solar Heat gain coefficient for the building shell material cannot be overemphasized. This was illustrated by Brent Cross South Limited (2017) as shown in figure 4 and figure 5 below. Notice the view (8) and (9) in shows the variation of solar radiation on uniform building shell.it can be concluded that the glazing selection of the façade should vary with height and orientation. For example, the use of a glazing with a lower solar heat gain coefficient (SHGC) on west windows will usually reduce the building's cooling load.

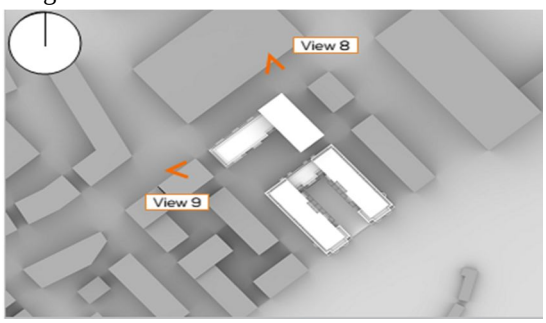


Figure 2: The layout of a proposed Scheme for Brent Cross South at London

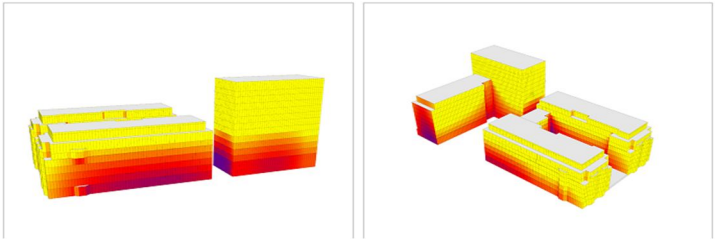


Figure 3: View (8) and (9) showing the heat and light distribution (Brent Cross South Limited, 2017)

C. Common Daylighting Solution in Museum

Light Shelf is generally a horizontal or nearly horizontal baffle positioned inside and/or outside of the window facade. The light shelf can be an integral part of the facade or mounted on the building Light shelves are not standard, off-the-shelf products.

Buildings with low ceilings usually provide too much light directly below the skylight and too little to the sides of the skylight. If laser-cut panels are used in an inverted V or inverted pyramid structure below a skylight, down coming light may be deflected over the ceiling, improving the distribution of light to the interior.

Louvers and blinds are classic daylighting systems that can be applied for solar shading, to protect against glare and to redirect daylight. Exterior louvers are usually made of galvanised steel, anodised or painted aluminium, or plastic (PVC) for high durability and low maintenance. Interior venetian blinds are usually made from small- or medium-sized PVC or painted aluminium. The slats can be either flat or curved. Slats are usually evenly spaced at a distance that is smaller than the slat width so that the slats will overlap when fully closed. Slat size varies with the location of the blinds: exterior, interior, or between the panes in a double-paned window. Exterior slats are usually between 50 and 100 mm wide; interior slats are usually 10 to 50 mm wide.

Dynamic solar blades allow the system to adapt and adjust its size based on the amount of daylight available. The dynamic solar blades, when rotated, scale (up and down) the amount of light that the system lets in ensuring that it is always the optimum size. Controlled daylighting delivers any desired level of Light Transmittance (L.T.) from 3% - 70%. Dynamic daylighting will also provide any desired level of sun-shading any time of the day. (Konstantin, 2016)

A sun-tracking sensor also allows optimal position alignment of the solar blades to harvest daylight that would otherwise be lost due to the low incident angle of the sun early and late in the day. Solar blades are angled to diffuse light transmission to suit user preference.

Having reviewed the various daylighting systems, it can be concluded that the Quad-glazed polycarbonate sandwich panel with inbuilt solar blade, controlled by solar sensors and automatic or manual switch is of high sustainable tendency and highly recommended for during this paper. Lighting quality or visual performance, visual comfort and ease of seeing are some of the benefits of Quad-glazed polycarbonate sandwich panel daylighting. Daylight is a full spectrum source of visible light. Unlike artificial lights, which sometimes provide limited spectral range that is concentrated in the blue/green or yellow/green range, daylight is best suited to human vision. Daylight can also provide any illumination level through proper design.

In commercial buildings, interior lighting accounts for about 30 to 40% of electricity consumption. Auxiliary or secondary lighting source such as electrical generator will be reduced drastically if Quad-glazed polycarbonate sandwich panel daylighting is introduced in a building scheme. Thus reducing or eliminating carbon emission from this generators to achieve a near zero carbon footprint design and reduced energy.

III. RESEARCH METHODOLOGY

A. Case Study

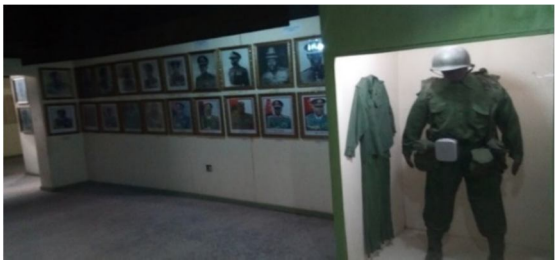
Case study of the daylighting features and internal lighting conditions of three existing museums was carried out in this paper. This was necessary to analyze critically the sustainability of the daylighting system adopted in their design. During Case study, physical information and characteristics of existing buildings samples was recorded for computer simulation of the impact of solar radiation on the building footprint and shell. Case study helps to get the actual experience of the users so that corrective measures can be put in place in the propose design. During Case Study, problems relating to circulation, security, Forms, Lighting efficiency, economic viability, merits and demerit were critically examined and compared to establish corrective and innovative design solutions recommended in this paper. It is easy to experience a museum as a tourist during case study. However to get factual experience of the long time users (staff and other daily users), there is need for an interview. The long time users' experiences affects the design decisions, to be recommended in this paper.

1) *Case Study One: (National War Museum Umuahia):* Designed by Frank Mbanefo Associate, with Structural Engineer being Agbim and Partners, Port Harcourt, River state. It was built by Mr. Joel Okechukwu Onyemelukwe (Principal Engineer), and Late Mr Lawrence O. Okany (superintended Engineer). The Museum was established in 1985 and features collection of objects of traditional and modern warfare. There are also outdoor displays of warships, military aircrafts, armoured tanks, and "Ogbunigwe" (bombs produced locally by Biafra during the Nigerian Civil War). It has the highest collection of the Nigerian civil war weapons from both the Nigerian military and the defunct Republic of Biafra. The design features modern architectural style with outdoor and indoor galleries as shown respectively in figure 4 and figure 5 below.

;

Source: (Emmanuel, 2018)

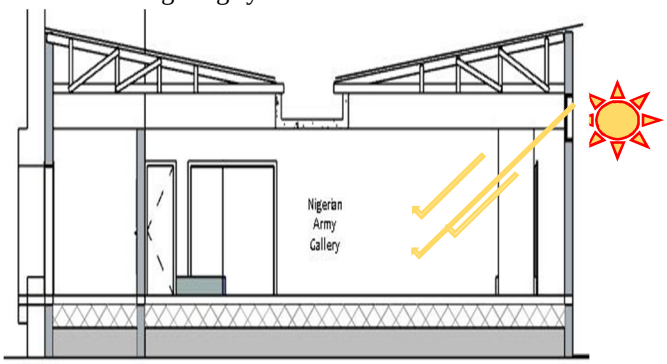
Figure 4: Outdoor Gallery with Biafran locally made armored vehicle, showing damage of heavy shelling from the civil war.



Source: (Emmanuel, 2018)

Figure 5: The indoor gallery featuring the combatant body amour.

a) *Lighting Analysis:* In figure 6 below, Clerestory window achieved though butter fly roof was adopted to achieve daylighting in the gallery area. Figure 7 shows artificial LED Lighting system introduced to compliment the daylight from the clerestory window. The artificial light is controlled manually from switches on the wall. The Outdoor gallery, completely depends on natural daylight without the aid of artificial lighting system.



Source: (Emmanuel, 2018)

Figure 6: Section Through Gallery, Showing Natural daylight through Clerestory window

Source: (Emmanuel, 2018)

Figure 7: Artificial LED Lighting combined with daylight from clerestory window.

2) *Case Study Two:* (National Museum Benin) Located in Benin, Edo State the Main building is housing the gallery and offices built of modern materials. The library and technical service buildings are detached bungalows from the main museum building. Nearby are the Oba's Palace, Oba Market and the Traditional Bronze-casters Guild. Other facilities of the Museum include: Crafts Shop Museum, Educational Services, Multipurpose Hall, Museum, kitchen, Museum Library, Park

a) *Lighting Analysis:* Natural and artificial lighting are employed. Figure 8 shows natural light into the gallery, through narrow clerestory windows. Artificial lighting elements such as fluorescent, spotlights are used in some galleries. The office spaces, Museum library, restoration unit are naturally and artificially lighted.

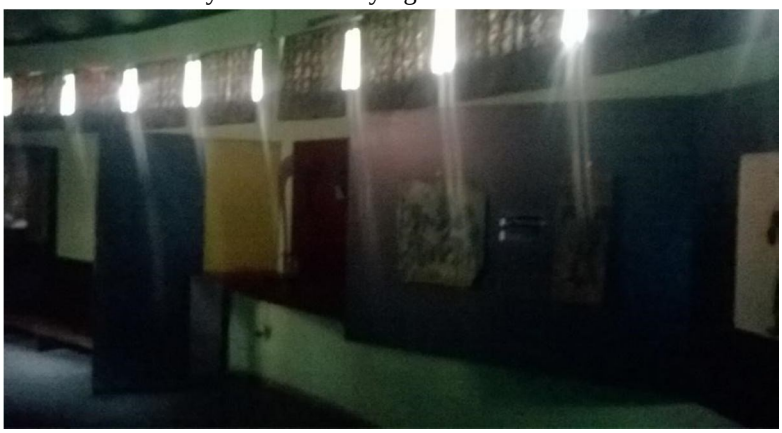


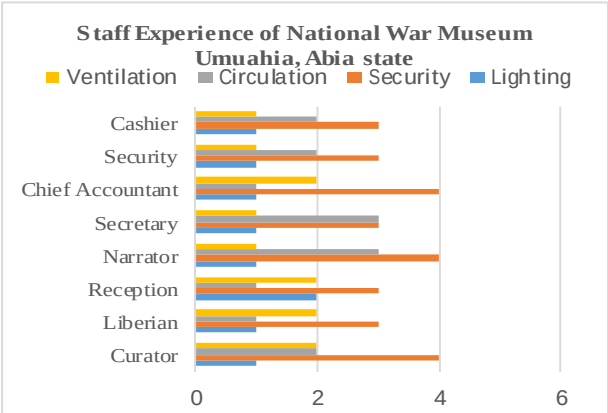
Figure 8: Museum Interior showing artificial lighting from the sun (Daniel, 2016)

3) *Case Study Three:* (The Louver Lens Museum, France) Located in France, the museum is designed by Japanese architects from SANAA, Kazuyo Sejima and Ryue Nishizawa. The structure is made up of five building of steel and glass. There are four rectangles and one large square with slightly curved walls whose angles touch. It is reminiscent of the Louvre palace, with its wings laid almost flat. The architects wanted to bring to mind boats on a river coming together to dock gently with each other. The facades are in polished aluminum, in which the park is reflected, ensuring continuity between the museum and the surrounding landscape. Its Daylighting System features skylight with roofs, partially in glass, reflecting a particular advantage to bringing in light, both for exhibiting the works and for being able to the sky from inside the building. The 360 meter long, steel and glass structure is integrated within a 20 hectare wasteland that was originally used as a coal mine before the 1960s. It is expected to attract 500,000 visitors every year and envisioned to help revitalize the post-industrial town. (Archdaily, 2018)

a) *Interview:* Selected Member of staff across the hierarchy of the Nigerian war museum was interviewed and interacted with, to get real-time daily work experience of the building and its environment. They were interviewed base of salient architectural parameters on the scale of 5 and their responses were tabulated in table 1 below, It can be noted that majority of the members of staff, rated the internal visibility poorly because of it is not functional.

Table 1: Result of Interview with staff at the scale of 5

S/N	Staff	Lighting	Security	Circulation	Ventilation
1	Curator	1	4	2	2
2	Liberian	1	3	1	2
3	Reception	2	3	1	2
4	Narrator	1	4	3	1
5	Secretary	1	3	3	1
6	Chief Accountant	1	4	1	2
7	Security	1	3	2	1
8	Cashier	1	3	2	1



Source: (Emmanuel, 2018)

B. Discussion and Findings

Having reviewed the above mentioned case study, it can be observed that Nigerian (local) Museum, depends heavily on auxiliary source of power for lighting. These museums although are purpose build, the design of their daylighting system were ignored and not properly considered. Diffused Artificial Lighting system is common to most of the local museums.

The present National War Museum Umuahia, heavily depends on Petrol electrical generator, which is a source of harmful carbon emission into the environment. Although the museum is designed to allow natural light into its galleries through clerestory windows as shown in figure 6, it can be seen to be ineffective as the interior of the museum becomes gloomy immediately the artificial lighting system is turned off figure 7 shows artificial light, complementing the natural daylight. It can be concluded that natural lighting has not been effectively adopted during the design and construction process of the museum. Thus the need for a new design.

The Louver Lens Museum is a pritzker award winning project on natural light because of its innovative louver lens skylight. It's technological and sustainability success can be attributed to its double glazing shell wall.

Natural lighting has been the major source during the day. The use of an innovative sustainable smart window glazing is highly recommended to avoid unbearable light intensity into the building. It can be noted from table 1 above that the Lighting within the National war museum has the lowest grade. Most of the users (members of staff) has a uniform negative internal lighting experience. Close to it is circulation and ventilation. Thus the need for an active and dynamic daylight system becomes paramount.

IV. CONCLUSION

This paper encourages Professionals in the Built Environment to work together in a holistic manner to ensure that all aspects of the building, including the building envelope, fabric, services and operational use of the Building Management Systems function together to ensure good daylighting system with low-energy and low carbon emissions. Daylighting designs can be evaluated according to energy saving potential, visual aspects and the control of solar radiation. It is also observed that significant amount of electricity can be saved by harnessing daylight for into the museum.

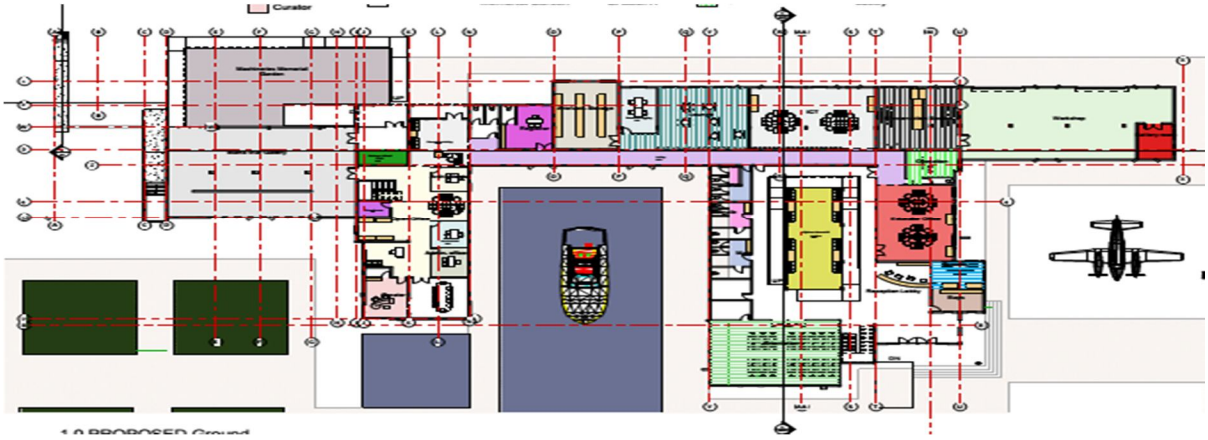


Figure 9: Ground Floor Plan with light well glazed with quad polycarbonate sheet and solar tubes at the atrium

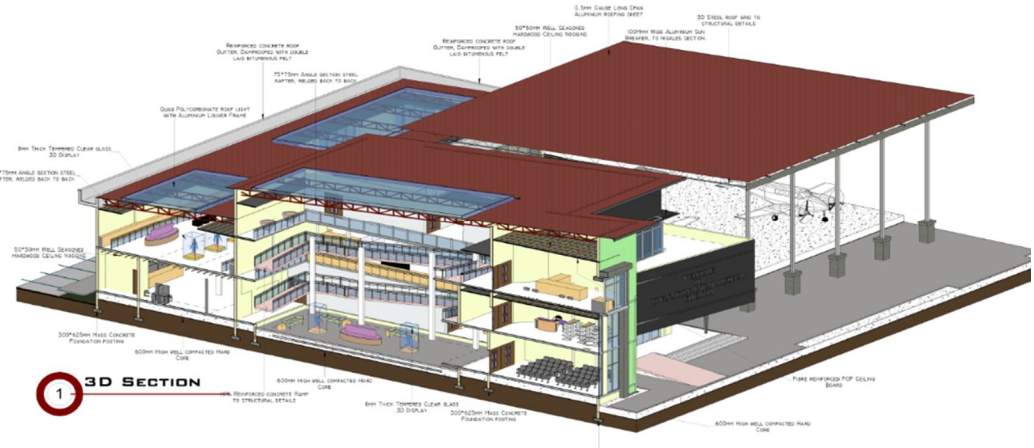


Figure 10: 3D Section showing Dynamic skylight in proposed design solution.

Figure 11: 3D Views showing the glazing at external wall

In figure 9 above, the Ground floor plan shows Odimegwu Ojukkwu's atrium which serves as light well for the core of the museum. Figure 10 shows section through gallery and atrium. The dynamic skylight is made of Quad polycarbonate sheet, with sandwich automatic solar blades, controlled by photo electric sensors. The skylight is carefully placed at the 3D Display in the first floor gallery. This allows for effective display of artefacts. Figure 11 features double glazed clear glass curtain wall to harness natural light into the research library and the orientation hall.

In Nigeria, the use of intelligent building solution is not always encourage because they depend on the available epileptic power supply. This paper stands to solve this problem by introducing a Dynamic skylight made of Quad Glazed polycarbonate Skylight with Dynamic (automated) Solar Blade over the atrium and various galleries. It depends majorly on solar panel and inverter for its required power to regulate. The translucent polycarbonate panels with intelligent solar blades are structurally mounted with and screwed to the aluminium glazing structure. In figure 13 below, external solar sensor, identifies the sun's position in relation to the glazing panel. The internal light sensor, measures room daylight level to adjust and rotate the solar blades in relationship with the external sensor, to achieve the desire requirement being placed on the user's wall controller.

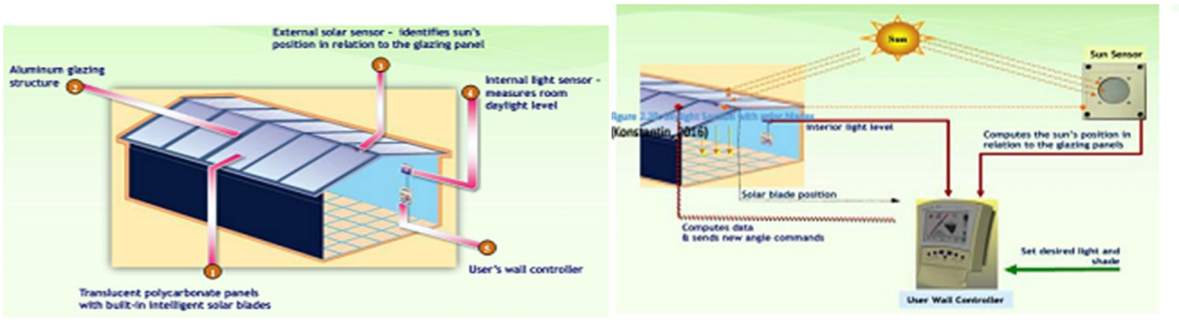


Figure 12: Dynamic skylight system (Konstantin, 2016)

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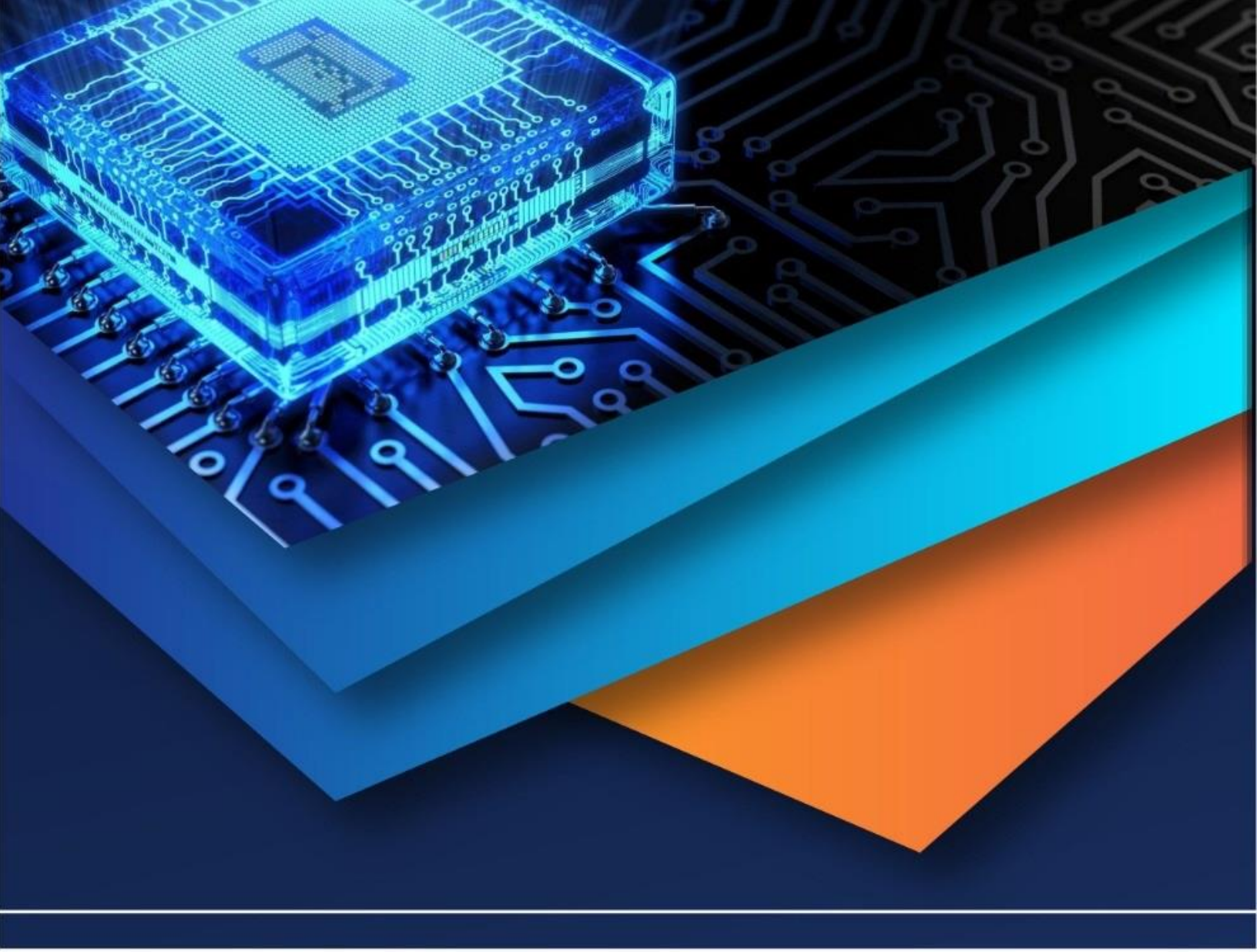

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