Assessment of Effective Usage of Daylighting Strategies in Selected University Libraries

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Abstract

The use of daylighting has traditionally been a desirable building feature and a hallmark of good design. In educational facilities, daylighting has frequently been acknowledged as a practical source of energy savings and visual comfort. Efficient use of daylighting in library buildings has a positive impact on the wellbeing and productivity of users. However, the effectiveness of daylighting strategies requires a balance between visual comfort, energy savings, and the preservation of library collections. This paper employs qualitative method through desktop reviews for the international case studies and physical observation for assessing the selected Nigerian case studies. The Hebei University of Science and Technology Library, University of Birmingham's Library, Hezekiah Oluwasanmi Library (Obafemi Awolowo University), Kenneth Dike Library (University of Ibadan) were purposively selected to examine daylighting strategies used in the selected university library buildings and assess how effective these strategies are. The case studies were assessed in line with 5 daylighting strategies namely; building orientation, building form, window design and placement, shading devices and skylight on a scale of 1-5 where 1 is very bad usage and 5 is very good usage. The study revealed that building orientation in each case was rated "very good", building form was effectively employed in all four case studies, the window placement of all case studies was rated between very good and good and the use of shading devices and skylight was used in 3 of the case studies. To achieve proper or effective daylight in the design of university libraries, architects and other stakeholders should consider building orientation, building form, window design and placement, shading devices and skylights.

Keywords*: Daylighting, Daylighting Strategies, Energy Efficiency, University Library, Visual Comfort.*

Introduction

University libraries are renowned architectural structures associated with higher education, serving as vital hubs for information, services, learning environments, and social connections (Bakr & Nagy, 2020). These libraries play a crucial role in providing students access to research materials, data sources, and various services, emphasizing the significance of their appearance and overall design (Klain, Gabbay & Shoham, 2019).

Visual comfort and energy efficiency are paramount in university libraries, making them spaces not only for reading, studying, and accessing digital resources but also for fostering social gatherings (Buchanan, McKay & Makri, 2019).

One essential aspect influencing the user experience in these libraries is daylighting (Kurniasih, Musdinar & Rachmanto, 2020). Daylighting refers to the visible light from sunrise to sunset, commonly known as natural lighting or sunshine (Kurniasih et al., 2020). Incorporating natural light, direct sunshine, and skylights into the building's interior spaces helps reduce dependence on artificial lighting, during the day and promotes energy conservation (Aram & Alibaba, 2018). Daylighting offers a well-balanced distribution of wavelengths suitable for daily tasks and visual comfort, making it conducive to creating visually engaging and productive environments for library users (Saraswati, Wibawa, Saputra, Path, Increasing, Safety, Prihatiningrum, Anom, & Seftyarizki, 2021).

The primary objective of daylighting is to provide efficient, high-quality light while minimizing issues like direct glare, reflecting layers, and surplus light ratio (Saraswati et al., 2021). Different sources of natural light, such as direct sunlight, a clear or cloudy sky, and reflections of the surrounding landscape and buildings, each offer unique characteristics in terms of quantity, heat, colour, dispersion, and energy efficiency (Kurniasih, Musdinar & Rachmanto, 2020). Creating well-lit spaces can be achieved through substantial windows or glass walls, covering at least 1/6 of the floor area, and allowing ample daylight to fill the interior (Kurniasih, Musdinar & Rachmanto, 2020).

Furthermore, a library's layout, including secluded reading areas and crowded reading halls, can influence students' educational experience and perception of the university (Bakr & Nagy, 2020). Numerous efforts have been made to explore the psychological

and physiological effects of daylighting on human beings (Osibona, Solomon & Fecht, 2021). Studies have indicated that incorporating windows with views of natural landscapes enhances comfort and behaviour, demonstrating the connection between daylight and psychological well-being (Flynn, Fies, Hendrick & Martyniuk, 2013).

Ambient lighting significantly influences user behaviour, impacting their impression of the surroundings and overall sense of well-being (Allan, Garcia-Hansen, Isoardi, Smith, 2019 & Knoop, Stefani, Bueno, Matusiak, Hobday, Wirz-Justice, Martiny, Kantermann, Aarts, Zemmouri, Appelt & Norton, 2020).

Consequently, this paper aims to bridge this research gap by evaluating the implementation of daylighting strategies in a specific typology, such as university library designs. The purpose of the study is to illuminate the significance of integrating efficient daylighting strategies to improve user comfort and mitigate thermal discomfort.

Literature Review

Daylighting

Daylighting is a fundamental aspect of architectural design, crucial for creating welcoming and efficient learning environments (IEA, 2010). It has garnered increased attention in recent years due to its ability to enhance visual comfort, improve energy efficiency, and positively impact human well-being, particularly in university library design (Iommi, 2018). Emphasizing daylighting in building design not only saves energy but also contributes to user comfort, performance, and overall satisfaction by reducing the need for artificial lighting and its associated costs (Li, 2010; Su, Zhang, Liu, Luo, Lian & Liang, 2020).

Daylighting serves as a control architecture technique, influencing user behaviour and perception. The quality and quantity of daylight transmitted through windows directly affect the ambience and psychological well-being of library users (Kilic & Hasirci, 2011).

Daylight transmitted through windows can be categorized into three types: diffuse light, direct transmitted light, and redirected transmitted light, and its fluctuations are attributed to the movement of the sun, altering the direction and quantity of natural light that enters a space through windows or a roof (Othman & Mazli, 2012). Achieving systematic and optimal daylighting can be

challenging for designers and building owners, considering various factors such as building orientation, window size, control systems, and maintenance (Aram & Alibaba, 2018).

The benefits of adequate daylight are profound, impacting users' physical and psychological health, comfort, productivity, and functionality. Environmental factors, including daylight, offer opportunities to influence user behaviour by thoughtfully measuring and controlling them. As light significantly influences behaviour, factors like brightness, sunshine, and window views play a crucial role in shaping the perception of space (Kompier, Smolders, van Marken Lichtenbelt & de Kort, 2020).

In educational settings, ineffective daylighting can lead to adverse effects on behaviour, potentially affecting academic achievement. Understanding the impact of daylight on users' behaviour in library spaces is crucial to improving the quality of daylighting in study rooms and addressing the lack of research in this area (Aram & Alibaba, 2018). By prioritizing effective daylighting strategies in library design, educational institutions can create conducive and inspiring learning environments for their students.

Daylighting Strategies

Daylighting strategies and architectural design are interconnected, necessitating early consideration during the building's design phase (Kilic & Hasirci, 2011). Thus, incorporating daylighting requires the integration of various viewpoints and expertise. Daylighting is a critical element that can significantly impact how people utilize library facilities (Kompier et al., 2020). Daylighting strategies rely on the presence of natural light, which is influenced by the building's orientation and its surroundings, including nearby obstacles to the north and south.

Additionally, climate plays a crucial role in lighting techniques, making it essential to consider seasonal changes, current weather conditions, ambient temperatures, and sunlight availability. To plan for effective daylighting, the initial step is to assess the environment and determine the daylighting potential for each facade of the proposed building (IEA, 2010).

Incorporating effective daylighting into a building requires careful consideration of specific architectural elements, such as building shape and orientation, the implementation of shading devices, the choice of glass material, and the design of

window opening size and spacing. Striking the right balance in providing optimal daylighting while mitigating any potential negative consequences is crucial to creating a well-lit and comfortable space. By taking into account these factors, designers can achieve a harmonious blend of natural light, enhancing the overall user experience and minimizing any drawbacks associated with excessive or poorly managed daylighting (Ramlan, R. A. 2014).

I. Building Orientation: Proper construction orientation plays a crucial role in maximizing access to natural light. The orientation of a building significantly influences the control of heating, cooling, and daylight within the space (Morsali, Akbarian & Hamed Zar Gari, 2021).

By strategically aligning the structure to capitalize on the sun's movement throughout the day, both daylight penetration and the need for artificial lighting can be effectively managed. For instance, in Figure 1 below, orienting the building's long side towards the east-west axis can facilitate passive heating or cooling on a seasonal basis, optimizing energy efficiency and creating a more comfortable environment (Bakr & Nagy, 2020).

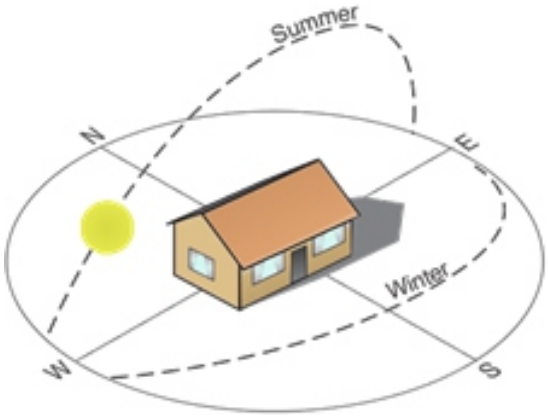

Figure 1: *Orientation of building*
Source: (Bakr & Nagy, 2020)

ii. Building Form: Building footprints come in diverse shapes, each with a unique approach to harnessing daylight within a space. Whether square, L-shaped, U-shaped, linear and thin or long and narrow in Figure 2, each form has its daylighting advantages. Long and narrow footprints are particularly advantageous for maximizing natural light penetration into the building.

Additionally, organizing buildings as a series of wings can help save on land while still ensuring ample access to daylight, offering an efficient and sustainable design solution (Bakr & Nagy, 2020).

Figure 2: *Building Footprints*
Source: (Bakr & Nagy, 2020).

iii. Window Design and Placement: Effective daylighting relies on careful consideration of window location and design. Strategic window placement is essential to maximize natural light while minimizing glare, enhancing visual comfort, and reducing energy consumption. Windows serve as the primary means of regulating the amount of heat, solar energy, natural light, and light intensity within the building, making them crucial for creating an optimal daylighting environment (Bakr & Nagy, 2020).

The amount of usable daylight in a space is influenced by the positioning of openings and the quantity of light that enters the area. When selecting the placement of windows, designers should also take into account the connection between occupants' outside view and eye level. By carefully planning the location and design of windows, designers can create a well-lit and visually engaging space that promotes both energy efficiency and occupants' well-being (Muhammad & Aliyu, 2021).

iv. Shading Systems: Proper shading systems, such as movable blinds, shades, or exterior overhangs, can effectively manage the amount of direct sunlight entering a building while still allowing diffused light to illuminate the space. These shading systems enable occupants to adjust and control the level of shading based on their specific needs and preferences. By using these mechanisms, occupants can strike a balance between natural light and glare reduction, ensuring a comfortable and visually pleasing environment within the building (Xue, Wang & Wang, 2021).

v. Skylight: Diffuse skylight strategies can be utilized under both clear and overcast skies. However, the handling of direct sunlight is the most crucial aspect distinguishing these strategies (Othman & Mazli, 2012). Daylighting faces the challenge of solar shadowing, except for facades oriented towards the North or South Pole (in the northern or southern hemisphere, respectively).

To address glare, solar shading techniques may be employed, particularly when glare is a minor concern due to direction and obstacles. It is important to note that glare protection and solar shading serve different purposes and require distinct design considerations. Glare protection focuses on reducing excessive brightness in the visual field, considering skylights and reflected sunlight in addition to direct sunlight. On the other hand, solar shading primarily aims to

shield against direct sunlight for thermal control. While systems providing sun shade help minimize overheating, they may not be sufficient to effectively address glare-related issues (Gkanias, Risse, Mangan & Webb, 2019).

This study may be limited by the purposive sampling method adopted for the selection of case studies, however, the research provides an in-depth assessment of effective usage of daylight strategies, from different perspectives.

Methodology

This research is based on a qualitative method that employs an architectural case study research approach. A total of 4 case studies were purposively selected from Europe, Asia and Africa namely; The Hebei University of Science and Technology Library (Tianjin, China), University of Birmingham's Library (Birmingham, United Kingdom), Hezekiah Oluwasanmi Library (Ile-Ife, Nigeria), Kenneth Dike Library (Ibadan, Nigeria).

The data from the foreign case studies were collected using online published literature and documentaries, while for the Nigerian case studies, data was collected through physical observation by the researchers using an observation guide, sketches and photographs. The data collected were descriptively analysed against Five (5) identified daylighting strategies from literature namely; Building Orientation, Building Form, Window Design and Placement, Shading System, and skylight. The result was presented descriptively using a table.

The case studies were assessed based on the effective usage of the 5 identified daylighting strategies using a scale of 1-5 where 5 = very good use, 4 = good use, 3= fair, 2= bad, and 1= very bad.

Results and Discussion

Table 1: Assessment of Daylighting Strategies Usage in the Selected Case Studies.

No	Daylighting Strategies	Names of Case Studies	Very Good	Good	Fair	Bad	Very Bad	Not Used
1	Building Orientation	Case study 1 - The Hebei University of Science and Technology Library.						
		Case study 2 - University of Birmingham's Library.						
		Case study 3 - Hezekiah Oluwasanmi Library, Obafemi Awolowo University.						
		Case study 4 - Kenneth Dike Library University of Ibadan.						
2	Building Form	Case study 1 - The Hebei University of Science and Technology Library.						
		Case study 2 - University of Birmingham's Library.						
		Case study 3 - Hezekiah Oluwasanmi Library, Obafemi Awolowo University.						
		Case study 4 - Kenneth Dike Library University of Ibadan.						
3	Window Design and Placement	Case study 1 - The Hebei University of Science and Technology Library.						
		Case study 2 - University of Birmingham's Library.						
		Case study 3 - Hezekiah Oluwasanmi Library, Obafemi Awolowo University.						
		Case study 4 - Kenneth Dike Library University of Ibadan.						
4	Shading System	Case study 1 - The Hebei University of Science and Technology Library.						
		Case study 2 - University of Birmingham's Library.						
		Case study 3 - Hezekiah Oluwasanmi Library, Obafemi Awolowo University.						
		Case study 4 - Kenneth Dike Library University of Ibadan.						
5	Skylight	Case study 1 - The Hebei University of Science and Technology Library.						
		Case study 2 - University of						

Building Orientation

Based on the data presented in Table 1, it can be observed that the study affirms the effective utilization of building orientation in all four case studies. The evaluation of building orientation in each case was rated "very good". In all 4 case studies and Figure 4-7, the long side faces the east-west axis which indicates a proper building siting. This suggests that the chosen orientations successfully contributed to achieving adequate natural daylight within the library spaces.

These results align with previous research, such as the work by Favero, Lowden & Bresin, (2023), emphasizing the significance of building orientation in educational facilities. Consequently, this study underscores the importance of deliberate building orientation as a crucial element for optimizing daylighting strategies in university libraries.

Figure 4: *Plan showing the building orientation of The Hebei University of Science and Technology Library.*
Source: Arch daily

Figure 5: *Plan showing the building orientation of the University of Birmingham's Library.*
Source: Arch daily

Figure 6: *Plan showing the building orientation of the Hezekiah Oluwasanmi Library, Obafemi Awolowo University.*
Source: Google

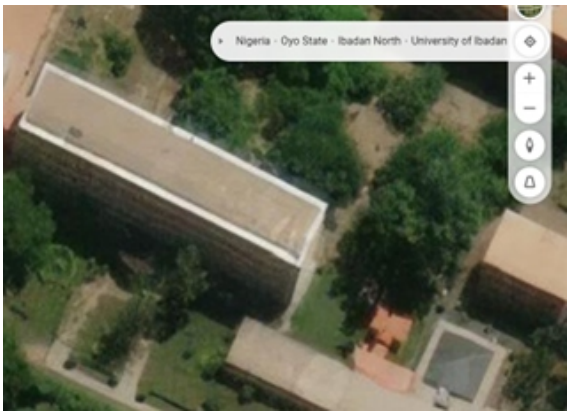

Figure 7; Plan showing the building orientation of the Kenneth Dike Library University of Ibadan.
Source: Google

Building Form

Similarly, based on the findings presented in Table 1, the study further shows that the building form was effectively employed in all four case studies. In each of these instances, the utilization of building form received a rating of "very good,", where case study 1 is having mixture of basic shapes as shown in figure 8, case study 2 has a mixture of triangle and rectangle forms as shown in figure 9, case study 3 having a U shape form indicated in figure 10, while case study 4 is having a L shaped and rectangle form as illustrated in figure 11 which indicates that it significantly contribute to achieving ample natural daylight within the library spaces.

The positive rating for building form suggests that the architectural design and shape of these libraries were optimized to enhance daylight penetration throughout the interior spaces. Such an approach is crucial for achieving energy efficiency, occupant comfort, and promoting a sustainable and user-friendly environment in university libraries (Verma, Iyengar, Setia & Dubey, 2021).

By effectively integrating daylighting strategies into the building form, libraries can create a well-lit and inviting atmosphere that positively impacts the learning and working experience of the library users.

Figure 8; Ground floor plan showing the building form of The Hebei University of Science and Technology Library.
Source: Archi daily

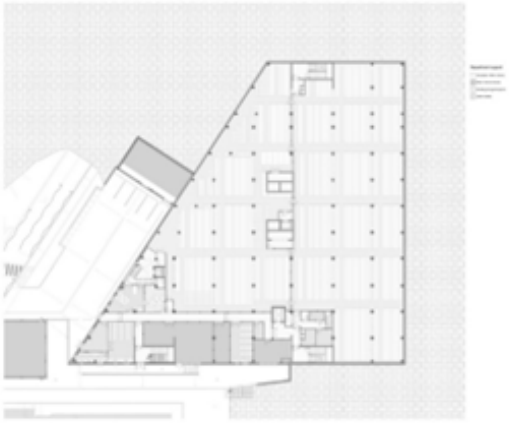

Figure 9: *Ground floor plan showing the building form of University of Birmingham's Library.*
Source: Archi daily

Figure 10: *Ground floor plan showing the building form of the Hezekiah Oluwasanmi Library, Obafemi Awolowo University.*
Source: Researchers field work

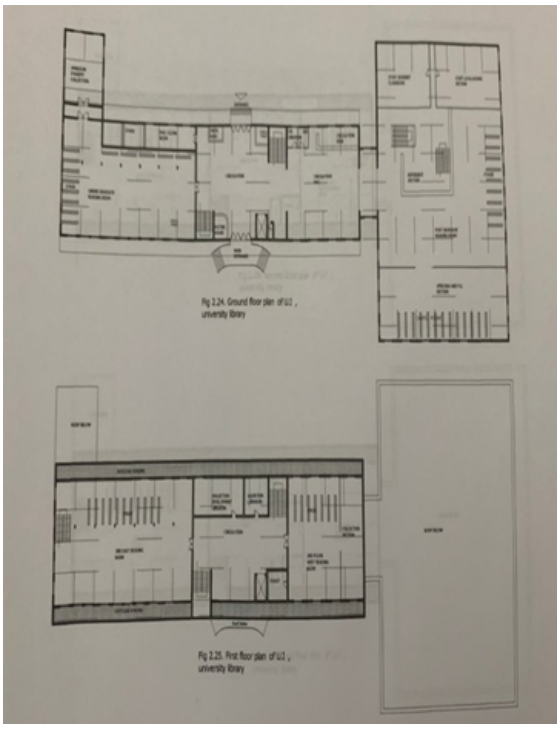

Figure 11; Floor plan showing the building form of the Kenneth Dike Library University of Ibadan.
Source: Researchers fieldwork

Window Design and Placement

Analyzing the information provided in Table 1 sheds light on the successful application of window design and placement in case study 2, specifically in the University of Birmingham's Library, as illustrated in Figure 13. The rating of "very good" is attributed to the strategic positioning of windows, not confined to just the west and east axis but also encompassing the reading area. Strategic window placement is crucial for optimizing natural light while minimizing glare. This underscores the noteworthy role played by the window design and placement in this library, making a substantial contribution to the abundant presence of natural daylight within its interior spaces.

In contrast, case study 1 (The Hebei University of Science and Technology Library), case of case study 4 (Kenneth Dike Library, University of Ibadan), and case study 3 (Hezekiah Oluwasanmi Library, Obafemi Awolowo University) received a "good" rating, illustrated in figures 12, 13 and 14, respectively. Despite a slightly lower rating compared to case study 2, these figures still signify that the window design and placement in these libraries were effective in providing adequate natural daylight for their interior spaces.

In summary, the study emphasizes the crucial role of appropriate window design and strategic placement in enhancing daylighting strategies, as evidenced by past studies (Muhammad A.M. and Aliyu I.G., 2021). This contributes not only to energy efficiency but also to the creation of a healthier and more comfortable environment for users in university libraries.

Figure 12: *An interior view showing the window design and placement of The Hebei University of Science and Technology Library.*

Figure 13: *An elevation showing the window design and placement of University of Birmingham's Library.*
Source: Archi daily

Figure 14: *An interior view showing the window design and placement of the Hezekiah Oluwasanmi Library, Obafemi Awolowo University.*
Source: Google

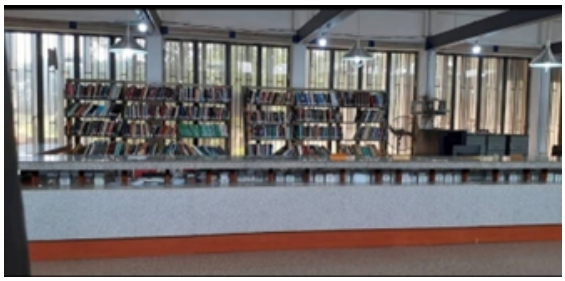

Figure 15: *Floor plan showing the building form of the Kenneth Dike Library University of Ibadan.*
Source: Google

Shading System

Based on the data presented in Table 1, the study reveals that the shading system used in case study 3 (Hezekiah Oluwasanmi Library, Obafemi Awolowo University) use of horizontal concrete fins to reduce the amount of direct sunlight entering a building while still allowing diffused light to illuminate the space as illustrated in figure 17, was rated as "very good." This indicates that the shading system implemented in these libraries was highly effective in controlling and optimizing daylight levels, ensuring a comfortable and well-lit environment.

On the other hand, in case study 2 (University of Birmingham's Library), the use of vertical aluminium fins and in case study 4 (Kenneth Dike Library, University of Ibadan) the use of Brise soleil, the shading system used received a rating of "good." illustrated in figures 16 and 18, respectively. While slightly lower than the rating in case study 3, it still signifies that the shading system in these libraries was successful in

managing natural light to achieve a balance between daylighting and glare control. Notably, in case study 1 (The Hebei University of Science and Technology Library), shading device wasn't used as part of the daylighting strategy.

The study's findings emphasise the importance of a well-designed shading system in daylighting strategies for university libraries. It demonstrates that when implemented effectively, shading systems can significantly promote sustainability and user-centric library design (Xue, Wang, Wang, 2021).

Figure 16: *Use of vertical aluminium fins as shading device of University of Birmingham's Library.*
Source: Archi daily

Figure 17: *Use of horizontal concrete fins as shading device of the Hezekiah Oluwasanmi Library, Obafemi Awolowo University.*
Source: Researchers field work

Figure 18: *Use of Brise soleil as shading device of the Kenneth Dike Library University of Ibadan.*
Source: Researchers fieldwork

Skylight

Based on the data presented in Table 1, the study shows that the skylight used in case study 1 (The Hebei University of Science and Technology Library) and case study 2 (University of Birmingham's Library) was rated as "very good." As illustrated in Figures 19 and 20, respectively. This indicates that the skylights implemented in these libraries were highly effective in controlling and optimizing daylight levels, contributing to a comfortable and well-illuminated interior space.

On the other hand, in case study 3 (Hezekiah Oluwasanmi Library, Obafemi Awolowo University), the skylight received a rating of "good," as shown in Figure 21, indicating that it still played a significant role in enhancing daylighting strategies, although its effectiveness might have been slightly lower compared to the two "very good" rated case studies. Notably, in case study 4

(Kenneth Dike Library, University of Ibadan), a skylight wasn't used as part of the daylighting strategy.

The study's findings emphasize the positive impact of well-designed skylights in promoting sustainability and user experience within university libraries. As such, by effectively utilizing skylights in combination with other daylighting strategies, libraries can create an eco-friendlier and inviting space for their users (Gkanias et al., 2019).

Figure 19: *An exterior view showing the skylight used in The Hebei University of Science and Technology Library.*
Source: Archi daily

Figure 20: *An interior view showing the skylight used in the University of Birmingham's Library.*
Source: Archi daily

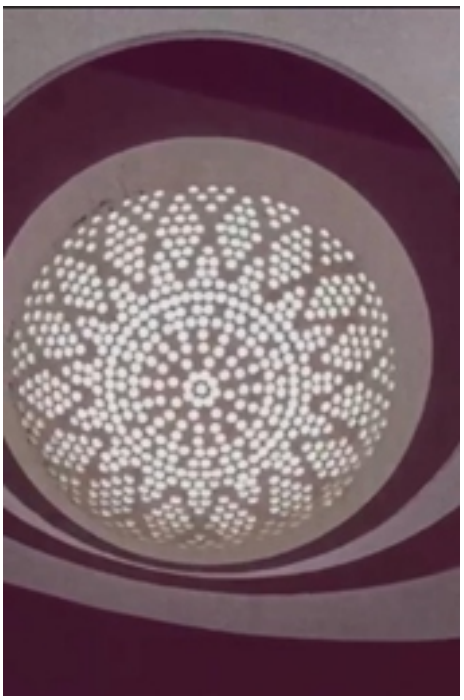

Figure 21: *An interior view showing the skylight used in the Hezekiah Oluwasanmi Library, Obafemi Awolowo University.*
Source: Researchers fieldwork

Conclusion and Recommendation

The purpose of this study was to investigate the effectiveness of various daylighting strategies in university libraries and their impact on visual comfort, energy efficiency, and preservation of data collections. Four case studies were analysed, focusing on building orientation, building form, window design and placement, shading system, and skylights as the key design considerations for optimizing daylighting strategies.

In all four case studies, building orientation was effectively utilized and rated between "very good" and "good." This success

indicates that thoughtful building orientation plays a pivotal role in achieving sufficient natural daylight within library spaces, supporting earlier studies emphasizing its importance in educational facilities.

Building form also proved to be a crucial factor, with a consistent "very good" rating in all case studies. The architectural design and shape of the libraries were optimized to enhance daylight penetration, contributing to energy efficiency, occupant comfort, and a sustainable, user-friendly environment.

Regarding window design and placement, case study 2 demonstrated the highest effectiveness, rated as "very good." While case studies 1, 3, and 4 achieved slightly lower ratings of "good" and "fair," they still effectively provided adequate natural daylight. Proper window design and strategic placement are essential in enhancing daylighting strategies, creating healthier and more comfortable environments for library users.

The study identified the shading system's significance, particularly in case study 3, where it was rated as "very good." Effective shading systems play a vital role in controlling and optimizing daylight levels, ensuring a comfortable and well-lit environment.

Skylights were found to be highly effective in case studies 1 and 2, with a rating of "very good." In case study 3, their effectiveness was still notable, receiving a "good" rating. The absence of a skylight in case study 4 indicated its potential contribution to daylighting strategies and user experience.
Embracing the recommendations based on these findings, university libraries can optimize their daylighting strategies, leading to improved energy efficiency, sustainability, and enhanced user experiences.

Collaboration between architects, built environment professionals, and library stakeholders is crucial to ensuring successful daylighting implementation from the early stages of design. A user-centric approach will ultimately create inviting, well-lit spaces that positively influence the overall library environment.

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