Design of Passive Daylighting Strategies to Enhance Thermal Comfort in a Mixed-use Facility

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Abstract- ***This publication focuses on the implementation of passive daylighting strategies to enhance thermal comfort in a mixed-use facility. Mixed-use facilities combine commercial, residential, and other functional spaces in a single building, often facing challenges in balancing natural lighting, thermal comfort, and energy efficiency. Natural daylighting enhances well-being and productivity but can lead to heat gains, especially in hot climates. Implementing passive cooling strategies such as natural ventilation and thermal mass can help manage indoor temperatures and improve thermal comfort. These strategies may be insufficient in delivering adequate illumination, necessitating the use of additional artificial lighting and the resultant increase in energy consumption. This study aims to effectively integrate passive daylighting techniques in a mixed-use facility to improve the thermal comfort of interior spaces. To tackle the research questions, we utilized a Qualitative research approach, which involved employing various data collection and analysis methods. The study incorporated both primary data, gathered through case studies and observations, and secondary data, obtained from scholarly articles, books, and industry reports. The case studies were meticulously chosen to find potential solutions to the research questions. Some of the significant findings observed in the selected case studies demonstrated the effective implementation of passive daylighting strategies in the facility. These strategies included the use of light shelves, skylights, top-down windows, clerestory windows, light tubes, and solar shading devices. They not only enhanced the amount of light entering a space but also allowed for control over light penetration, ultimately improving the thermal comfort of the interior spaces in the selected facilities. The specific case studies that were selected played a crucial role in identifying and analyzing the intricacies of implementing these strategies within the proposed mixed-use facility. Their in-depth exploration provided valuable insights into ensuring the proper and effective execution of the strategies.***

Indexed Terms- ***Mixed-use facility, Passive Daylighting Strategies, Thermal comfort, energy consumption, energy efficiency.***

I. INTRODUCTION

The built-up environment forms one of the three vital needs of a human being, namely; food, clothes, and shelter. For the built environment to be efficient and effective, one of the most important factors is lighting. Lighting in Natural Light helps create healthier, brighter, happier, and safer spaces. Architecturally speaking, Natural Daylighting helps reduce energy waste and carbon footprints and helps in the overall sustainability of the building. (Clifford, 2022). The major purpose of natural lighting is to provide good and comfortable visibility for indoor and outdoor activities throughout the day, regardless of weather conditions. Daylighting is introducing natural light into an indoor environment to reduce the energy consumption by artificial light sources in the building. The amount and quality of illumination enable our indoor activities to be carried out effectively, especially during the night time, which is important to increase productivity and improve the quality of life (Onubogu, 2021). Natural light is a powerful architectural tool for the illumination of dark areas in a building or the environment. Nowadays, there are more tools than ever to harness daylight. From innovative reflective materials to advanced computer modelling, architects are increasingly using modern technology to light buildings more efficiently (Nihmiya, 2021).

The term ‘mixed-use’ is largely based on the place-making of the built form, which is an approach in urban design and planning concerned with creating social life in cities (Narvaez and Penn 2016). Mixing uses requires an appropriate combination of multiple uses, inside a single structure or place within a neighbourhood where a variety of living activities (living, working, shopping) are near (within walking distance) to most residential areas. Drawing on these conceptions of mixed land use, three urban design qualities are explored that derive from the spatial and economic processes of mixing uses: spatial location; the combination of uses that a building can accommodate, mainly commercial and residential functions; and the spatial form in which the mixing of uses takes place. The design qualities of location, use, and form are also susceptible to change in the built environment. Change is a constant factor and one of the most powerful drivers of change is in design. The change process is often one in which social shifts require a spatial physical reaction (Narvaez, 2016).

Mixed-use facilities, which combine commercial, residential, and other functional spaces within a single building, often face significant challenges in balancing the competing demands of natural lighting, thermal comfort, and energy efficiency. Conventional architectural design approaches may not adequately address these complexities, leading to suboptimal indoor environmental quality and increased energy consumption (Ander, 2003). On one hand, natural daylighting is widely recognised as a key factor in enhancing occupant well-being, productivity, and satisfaction (Boyce et al., 2003). Adequate and well-distributed daylight can reduce the reliance on artificial lighting, leading to significant energy savings (Littlefair, 1996). However, the influx of solar radiation can also contribute to undesirable heat gains, compromising thermal comfort, especially in hot and humid climates. On the other hand, implementing passive cooling strategies, such as natural ventilation and thermal mass, can help manage indoor temperatures and improve thermal comfort (Lechner, 2015). Yet, these strategies may not be as effective in providing sufficient illumination, leading to the need for supplementary artificial lighting and the associated energy consumption (Reinhart & Fitz, 2006). This research project aims to investigate the integration of passive daylighting strategies with passive thermal comfort techniques in the context of a mixed-use facility. By addressing this problem, the study can contribute to the development of more sustainable and user-centric building designs that optimize indoor environmental quality while minimizing energy usage (Ander, 2003). The findings can provide valuable insights for architects, engineers, and building professionals in the design and operation of mixed-use buildings.

II. LITERATURE REVIEW

As the significance of sustainable design develops, passive strategies such as daylighting have become increasingly critical in reducing the effects of the built environment. Greater understanding of how strategic passive daylighting shapes holistic visitor experiences could encourage its embrace in exhibition planning.

A. Daylighting

Daylighting plays a crucial role in creating an engaging and efficient environment for buildings while significantly reducing energy costs. It involves more than just daylight apertures such as skylights and windows; a complete daylighting system that helps to integrate these apertures with responsive lighting controls to reduce the need for electric lighting. Proper fenestration design, which involves the placement of windows to avoid direct sunlight on task surfaces and occupants' eyes, is essential. Additionally, the implementation of daylighting requires an integrated design approach, encompassing considerations such as building form, siting, climate, windows, skylights, lighting controls, and lighting design criteria. This holistic approach is vital for the successful integration of daylighting within a project. (Ander, 2016).

There are multiple sources of daylighting can be utilized in building design, some of these sources include:

- Exterior Light Reflection: This refers to the light that is reflected into a building from the ground, pavement, adjacent buildings, and other objects.
- Direct Sunlight: Direct sunlight is another source of daylighting. However, it is typically blocked from occupied spaces due to issues such as heat gain, glare, and UV degradation.

- Internal light reflection: internal light reflected off walls, ceilings, and other interior surfaces.
- The most common daylighting approaches make use of side lighting, top lighting, and atria; other techniques can be used, as well.

B. Passive Daylighting Strategies

Passive daylighting strategies promote the quantity and even distribution of daylight throughout a building by collecting natural light and reflecting it into darker areas of the building. What makes this a "passive" strategy is that the design elements do not require any special mechanical equipment or energy sources. As soon as the sun rises, the passive daylighting strategies collect and reflect light throughout the building. This type of system is incredibly beneficial both for building owners and visitors. You will use less energy to keep the building lit during the day. This, in turn, could save you money and help you reach sustainability and renewability goals (Gullotti 2009).

Architects use windows, skylights, tubular daylight, louvres, skylights, sloped glazing, solar light, ground-to-ceiling windows, light reflectors and shelves, and sawtooth roofs (Onubogu, Tan 2021).

C. Types of Passive Daylighting Strategies

The Passive daylighting strategies that were implemented in the proposed facility were mainly; Skylights, Light Shelves, Top-down Windows, and Clerestory Windows.

- Skylights

Skylights are known for their ability to provide a visual connection between the indoor and outdoor environment, which can enhance the overall aesthetic appeal of a building. They also offer sustainable building practices by reducing the need for artificial lighting during the day, thus saving energy. Additionally, skylights can improve indoor air quality by providing ventilation, which can prevent the buildup of moisture and harmful pollutants Overall, skylights are a cost-effective and eco-friendly solution for any building, which can add both aesthetic and functional value (Ander, 2016).

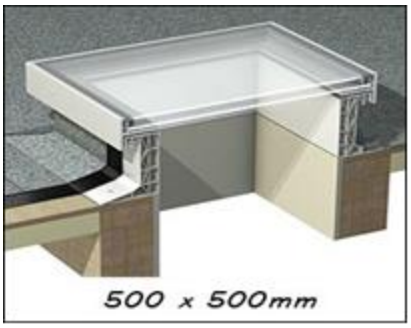

Fig 1: Showing Image of the skylight. (Source: Arch web & the skylight company 2014)

- Light Shelves

Light shelves are natural lighting apparatuses mounted on windows that reflect natural light from the outside onto the ceiling surface of an indoor room. This design reduces the amount of energy required for lighting while mitigating the issues of glare and illumination imbalance that arise from direct external natural light exposure. To optimize the performance of a light shelf, the height, width, angle, and material of the shelf are variables that require adequate control. Light shelves are commonly used in high-rise and low-rise office buildings, as well as institutional buildings, on the side of the building facing the equator to maximize sunlight exposure (Clifford, 2022)

Fig 2: Showing light shelf concept. Source: Pinterest, (2019)

- Clerestory Windows

Another important element in creating daylighting is the use of clerestory windows. These are high, vertically placed windows. They can be used to increase direct solar gain when oriented towards the equator. When facing toward the sun, clerestories and other windows may admit unacceptable glare. In the case of a passive solar house, clerestories may

provide a direct light path to polar-side (north in the northern hemisphere; south in the southern hemisphere) rooms that otherwise would not be illuminated. Alternatively, clerestories can be used to admit diffuse daylight (from the north in the northern hemisphere) that evenly illuminates a space (Clifford, 2022).

Fig 3: Showing Clerestory Windows. (Source, Pinterest, 2016)

D. Thermal Comfort

Thermal comfort refers to the state of mind that expresses satisfaction with the thermal environment. Achieving thermal comfort can have a positive impact on our well-being, productivity, and overall satisfaction. It is essential to create spaces that allow occupants to feel comfortable and perform at their best. (Rangel and Love 2023).

E. Factors that affect Thermal comfort in interior spaces

Aspects influencing thermal comfort within interior spaces can be classified into two primary categories: environmental factors and personal factors. These facets interact with each other, contributing to the overall assessment of whether individuals perceive the space as excessively warm or cold.

i. Environmental Factors:

- Air Temperature: The temperature of the air surrounding individuals is a crucial factor in determining their thermal comfort. This important metric is usually assessed using a thermometer to measure the ambient temperature. Elevated temperatures can result in discomfort and heat stress, while lower temperatures can lead to cold stress. Maintaining an optimal and comfortable temperature is essential for promoting well-being and productivity.
- Humidity: The level of moisture in the air is known as humidity. Excessive humidity can impede the evaporation of sweat, making it more challenging for people to stay cool. In spaces without air conditioning or when the outdoor weather impacts the indoor environment, the relative humidity may surpass 70%, causing discomfort.
- Radiant Temperature: Radiant temperature is the heat that emanates from objects like the sun, radiators, or hot surfaces. The existence of radiant heat sources can impact thermal comfort even when the air temperature is comparable. (Your, 2017).

ii. Personal Factors:

- Clothing Insulation: The type and amount of clothing individuals wear can affect their thermal comfort. Wearing too many or too few clothes for the environment can cause discomfort.
- Personal Preferences: Personal factors such as age, gender, weight, and fitness level can influence how individuals perceive and tolerate different temperatures. Some individuals may feel comfortable at a higher or lower temperature compared to others.
- Metabolic Heat: The level of physical activity individuals engage in at work affects the amount of heat they produce. More physically active individuals generate more heat and may require additional cooling mechanisms to maintain thermal comfort. (Your, 2017).

F. Study Area

Ikwerre LGA is a local government area located in the heart of the Niger Delta region of Nigeria, in Rivers State. The area is home to the Ikwerre people, an ethnic group with a rich cultural heritage that can be traced back several centuries. The origins of the Ikwerre people can be traced to the 15th century when they migrated from the Benin Kingdom and settled in the present-day Ikwerre LGA (Nwogu, 2021). The Ikwerre people established several autonomous communities, each with its traditional ruler and system of governance, which helped to maintain the cohesion and unity of the group (Okorie, 2019). Over the centuries, the Ikwerre people have played a significant role in the development of the

Niger Delta region. During the colonial era, they were actively involved in the palm oil trade, which was a major economic activity in the area (Eze, 2020). Many Ikwerre individuals also served in the Nigerian civil service and military, contributing to the nation-building process (Amadi, 2022). The Ikwerre people have a rich cultural heritage that is reflected in their language, customs, and traditional festivals. The annual Ogele festival, for instance, is a celebration of Ikwerre identity and heritage, drawing visitors from across the region (Obasi, 2021). The Ikwerre people have also been at the forefront of efforts to preserve their cultural traditions and pass them on to future generations.

Today, Ikwerre LGA is a thriving economic hub, with a diverse economy encompassing agriculture, commerce, and industry. The area is known for its production of palm oil, cassava, and other cash crops, as well as its vibrant markets and small-scale enterprises (Onyekwere, 2022). The Ikwerre people have also been at the forefront of efforts to promote sustainable development in the region, addressing challenges such as environmental degradation and climate change. Despite the challenges faced by the Ikwerre people over the centuries, they have remained resilient and continue to play a vital role in the development of the Niger Delta region. Their rich cultural heritage, strong sense of community, and entrepreneurial spirit have been instrumental in shaping the identity and character of Ikwerre LGA (Ofoegbu, 2018). As Ikwerre LGA looks to the future, the people remain committed to the sustainable development of their communities, while also embracing the opportunities presented by modernity. With their strong sense of identity and unwavering commitment to their cultural traditions, the Ikwerre people are poised to continue playing a leading role in the development of the Niger Delta region (Onyekwere, 2022).

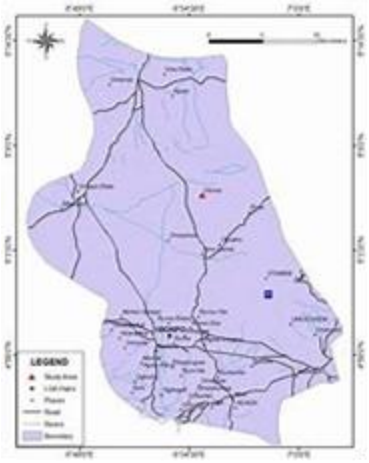

Fig 4: Showing Map of Ikwerre L.G.A. Source: Wikipedia (2017)

III. RESEARCH METHODOLOGY

The research methodology utilized in this study involved an exploratory literature review. This approach entailed analyzing existing research to gain valuable insights and evaluate the strengths and limitations of design strategies. The research encompassed a wide range of literature, including studies on the climatic conditions of Port-Harcourt, general design strategies for thermal comfort, and design strategies specifically tailored for hot, humid regions of Nigeria. These components formed the framework upon which design strategies for thermal comfort in the Faculty of Architecture building in Port-Harcourt, Nigeria, were determined. A preliminary review of the literature was conducted to provide a general overview and understanding of Passive Daylighting Strategies and their potential to enhance thermal comfort in a mixed-use facility. The qualitative research approach method was employed to gather crucial data for this dissertation. Primary materials were obtained through field investigations, case studies of relevant facilities, and literary works.

Case study

The application of daylighting strategies that enhance thermal comfort in existing mixed-use facilities was highlighted in case studies based on physical observation, exercises, and existing literature, including textbooks, publications, magazines, journals, and thesis reports. Additionally, data

collection and case studies from other countries were conducted online.

- Kingsway Towers

Kingsway Tower is a hallmark of modern architecture in Lagos, Nigeria, symbolizing the city's rapid urbanization and evolution. Standing as one of the tallest buildings in the region, it showcases not only impressive height but also innovative design that integrates functionality with aesthetic appeal. The tower's architecture embraces contemporary trends while respecting local context, featuring sleek lines and bold forms that create a striking profile against the Lagos skyline. Its materials and finishes reflect both modern styles and cultural elements, resonating with the identity of the city. Aimed at elevating Lagos's architectural landscape, Kingsway Tower serves as a catalyst for future developments, showcasing Nigeria's potential on the global stage and fostering pride in its urban development.

The building's design philosophy incorporates a passive daylighting system that maximizes natural light through large windows and strategically placed openings, reducing reliance on artificial lighting. Careful building orientation optimizes sunlight exposure while minimizing glare and overheating. Interior spaces are designed to ensure that natural light penetrates deeper into the floor plate, enhancing occupant comfort and productivity in key areas like lobbies and workspaces. By contributing to energy efficiency and lowering operational costs, the passive daylighting system positions Kingsway Tower as a leader in green building practices. Architectural features like overhangs and reflective materials effectively control solar gain, ensuring pleasant light quality throughout the day. Overall, Kingsway Tower not only redefines the Lagos skyline but also embodies a commitment to sustainability, functionality, and aesthetic appeal, crucial for shaping the future of urban development in the region.

- Daylighting Strategies:

i. Floor-to-ceiling glass windows: These windows allow natural light to penetrate deep into the building's interior, reducing the need for artificial lighting and providing occupants with access to natural sunlight and its associated health benefits.
ii. Light shelves: These are horizontal surfaces installed on the exterior of the building that reflect sunlight deeper into the interior. This helps to reduce glare and distribute natural light more evenly throughout the space.
iii. Atrium: The central atrium of the Kingsway Tower serves as a light well, bringing natural light into the heart of the building. This space also provides a visual connection to the outdoors and promotes interaction between occupants.

IV. RESULT AND DISCUSSION

The incorporation of passive daylighting strategies in the mixed-use facility has showcased its ability to improve thermal comfort within interior spaces. By regulating the quantity and dispersion of natural light, these strategies have effectively reduced solar heat gain, minimized the risk of overheating, and enhanced the overall thermal environment. The integrated design approach, which merges passive daylighting with other energy-efficient measures, has resulted in a substantial decrease in the facility's energy consumption. The amplified utilization of natural light has diminished the need for artificial lighting, leading to reduced electricity demand, while the improved thermal comfort has lowered the building's heating and cooling loads. The heightened thermal comfort and increased access to natural light have contributed to enhanced occupant satisfaction and well-being within the mixed-use facility. However, the integration of passive daylighting strategies into a mixed-use facility can present design challenges, such as harmonizing the requirements of distinct space types and ensuring appropriate daylight distribution. The effectiveness of these strategies can also be influenced by factors such as building orientation, climate, and occupant behaviour, necessitating careful consideration during the design process. The results of this study can guide the design of similar mixed-use facilities, providing a framework for the successful implementation of passive daylighting strategies to enhance thermal comfort. Continued research and development in this field can further optimize the performance and benefits of these strategies, contributing to the development of more sustainable and comfortable built environments.

CONCLUSION

In conclusion, the study aimed to develop a mixed-use facility in Port Harcourt that could accommodate commercial, recreational, and residential applications. This was achieved through the outlined steps and extensive research, including case studies and consultation with relevant reference materials. The resulting information informed the design of a mixed-use facility at Igwuruta Road, Port Harcourt, in Rivers State. The capability of the proposed mixed-use facility to serve as an attraction promoting connectivity between the different residents of Igwuruta is evident. It represents hope for revitalising the city and creating a strong economic future. It is recommended that the Rivers State Government consider adopting the master layout and architectural drawings and implement the proposed facility.and energy-efficient conference centers.

From the above research, it is no longer a hidden knowledge, the viability of the project as the proposed mixed-use facility will serve as an attraction that will help integrate connectivity between the different residents of Iqwuruta. It is also a sign of hope for the people in revitalising the city and creating a great economic future. Therefore, it is recommended that the Rivers State Government adopt the Master layout and Architectural drawings and implement the same

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