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Exploring Passive Design Techniques to Achieve Energy Efficiency in Regional Shopping Mall Design

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Abstract

Shopping Malls are high-end energy consumer in terms of scale of size and immerse footprint including the embedded retail activities requiring both functional and energy efficient strategies to achieve an indoor environment conducive to the teaming end users. However, considering the climatic disposition and geography of the project. This study intends to explore and apply passive design techniques to achieve energy-efficiency in the design of a regional shopping mall in such climate. Nigeria is confronted with a number of energy issues, including the inability to generate enough energy to fulfill the country's energy demands. The passive approach and other energy efficient strategies is here considered suitable in developing buildings that consume a lesser amount of energy. It is expected that energy efficiency may be accomplished by making the most use of existing renewable energy sources and other energy efficient appliances used in shopping malls and other public buildings. The use of materials and construction processes to aid designers and builders in generating designs at a lower cost and higher output, propelling the building industry to a new sustainable heights, is the thrust of this paper. Passive techniques are used to achieve ecologically friendly built environment and that of the future.

***Keywords**: Shopping mall, Climate, Passive design techniques, Materials*

1. Introduction

Energy efficiency is a low-cost way to achieve an environmentally friendly design that saves money and reduce greenhouse gas emissions. According to the Community Research and Development Centre CREDC (2009), energy efficiency has become a critical and urgent part of sustainable design, which is currently a global need. According to Janssen (2004), an increase in energy efficiency is defined as any action performed by a producer or consumer of energy products that reduces energy usage per unit of output while maintaining the quality of service given. According to the International Council of Shopping centres (ICSC), "a shopping mall is an enclosed collection of a variety of independent retail units, services, and parking spaces that were created and managed by a distinct management."

For example, in an illustration of the Mall of America in Bloomington, Minnesota, all of these activities are housed under one roof, with interconnecting corridors allowing people to go from one unit to another with ease. They also provide a place for individuals to mingle. The use of open space and the use of sustainable design in shopping malls are becoming increasingly popular across the world. As a result, existing shopping malls are opening, blending into the urban fabric, and constantly updating to compete with new shopping destinations. The utilization of new building materials provides retail malls new shapes and appearances.

Nigeria has a daily peak demand for 2,000GWh of electricity. Out of this, 65 percent of this is consumed by the residential sector, 20% by the commercial sector, and 10% by the industrial sector, with the remaining 5% exported to Niger, Togo, and Benin Republic. Only about 40% of Nigeria's population of over 140 million people has access to electricity, with the vast majority of these people living in urban areas. Consumers in areas where energy is available face regular power outages that last several hours. A recent study of 150 people performed in three major cities in Nigeria—Abuja, Lagos, and Benin City—found that more than 80% of individuals polled do not have access to power for up to 24 hours a day by Power holding companies. (Oyedepo, 2012)

The hot-humid environment, which is characterized by heat, sun glare and rain, necessitates a more sustainable approach to building designs, particularly those that use a lot of energy, such as shopping malls. There is a need to design for bioclimatic comfort in order to minimize energy consumption and boost interior thermal comfort. In this study, it is assumed that shopping malls consume a lot of energy and that the hot-humid environment of the study area contributes to this. The study is to investigate and use energy-efficient design concepts in the design of shopping malls in hot-wet/humid climates to address this notion. The passive technique is be used to design structures that consume a large amount of energy.

2. Literature review

2.1 Brief background of the study

Until the early twentieth century, passive tactics were the sole means to manage the indoor environment. It became a distinct profession with the advent of mechanical building services. The advancement of technology and the creation of new artificial systems for lighting and air conditioning, such as the air conditioning equipment invented by Willis H. Carrier in 1902 (Turner et al., 2002), made significant improvements to building internal thermal comfort. However, for a period of time, these innovative technologies and the availability of inexpensive energy caused architects to disregard the climatic factors of each place, leading to dependency on fossil based systems. As a result, the vast bulk of global energy consumption is directed at decreasing the influence of fossil energy consumption on the natural environment and humanity.

The types of building components and systems used in modern building design can either improve or deteriorate a structure's energy efficiency. The building envelope is an important factor in determining a structure's energy consumption. It encompasses everything that divides the building's interior from the outside environment, such as the doors, windows, walls, foundation, roof, and insulation. Various ways can aid in the improvement of the building envelope. Storm windows and doors, for example, can help to prevent heat loss when temperatures drop. Figure 1 shows how, in warm climates, windows with specific glass may let in daylight without boosting the temperature. Architectural solutions may be used to achieve improved energy efficiency over the whole lifetime of a building while designing the volume of the structure. However, this option is currently underutilized. (Josifas et al, 2011). Efficient energy resource utilization during a building's lifecycle is determined in part through the use of rational architectural and layout measures when planning the building volume.

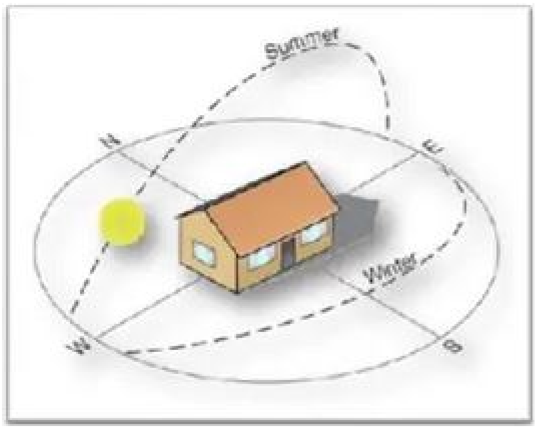

Figure 1: Sun path and Building Orientation (Image source: www.nachi.org)

2.2 Building Form and Orientation

Heat loss is best reduced by using a compact building shape with a low surface-to-volume ratio. However, as seen in Figure 2, a rectangular structure with one of its longer sides facing south can provide improved passive solar heating, day-lighting, and natural ventilation. Sunny south-facing rooms offer a high amenity value in addition to lowering energy expenses. The impact of architectural and layout solutions on a building's energy balance Compactness is one of the architectural and layout features of a structure. It is the capacity of a building volume to fit as much functional area within the external envelope (the entirety of exterior walls, windows, roof, and lower heated floor sections) as feasible.

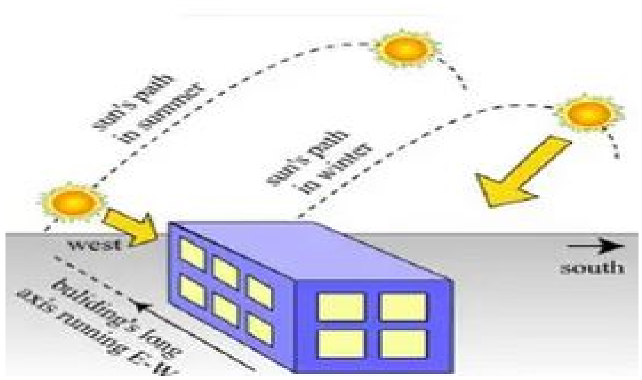

Figure 2: Building Orientation Source: www.hk-phy.org (2013)

3. Methodology

The first step established the theoretical underpinning for this research. Furthermore, it seeks to identify the analytical approach and topics to be addressed in the case study. This phase consists mostly of thorough literature evaluations of books, journal papers, research papers, and documents in order to find energy efficient design ideas that might be employed in the context of the research. The second phase included a second desk study to analyze and evaluate the data from the first and second phase investigations using quantitative and qualitative methodologies. The energy-saving concepts uncovered through the literature study were compiled and statistically analyzed to calculate the energy savings of characteristics that may be utilized in the setting of Port Harcourt.

4. Passive Design Techniques to Achieve Energy Efficiency in Shopping Mall Design

4.1 Thermal Comfort and Energy Efficiency

Thermal comfort is a subjective experience. That is the mental state that conveys contentment with the thermal environment. It is also that frame of mind that does not exhibit unhappiness with the temperature environment (Ogunsote, 1991). It is equal to conditions in which humans can sleep peacefully and work comfortably, and when the body's thermo-regulatory processes are under little strain. The following criteria are elements that improve energy efficiency and encourage thermal comfort of building occupants:

a) Window dimensions;

b) Window orientation; and

c) Shading device

a) Window dimensions;

The size of window apertures is a significant architectural feature for admitting daylight, air movement, cross-ventilation, and thermal comfort. For adequate cross-ventilation in hot-humid conditions, Gut and Ackerknecht (1993) propose that windows be big and completely openable, with inlets of a similar size on opposing walls.

b) Window orientation

According to Gut and Ackerknecht (1993), "openings in hot and humid climates should be situated according to the prevailing wind so that air may circulate through the internal space, hence improving thermal comfort." In her study on the impact of climate on the design and position of windows for buildings in Bangladesh, Ahmed (1987) advises that windows on western walls should be avoided since it is nearly difficult to shade them in all seasons. Liping

(2007) also emphasizes the need of avoiding east or west facing rooms for thermal comfort and energy efficiency.

c) Shading devices

Shading is the first line of defense against solar gain entry, and it may also lower an occupant's effective temperature by up to 80 degrees (Nick and Koen, 2005). Overhangs can be used to shade windows, preventing direct solar radiation from entering the structure. Watson and Labs (1983) classified shading devices into three types: solar transmission of glazing materials, internal shading, and outside window shades. The solar transmittance of a glazing material is described as its ability to allow or reject heat. Heat absorbing, heat reflecting, and tinted glazing are all discouraged by Watson and Labs (1983) and Gut and Ackerknecht (1993) while heat absorbing transparent and tinted glass, according to Watson and Labs (1983), inhibits sunlight transmission by absorbing heat inside the material itself. They claim that absorbed heat can make inhabitants uncomfortable since it increases heat to the inside via conduction and thermal radiation.

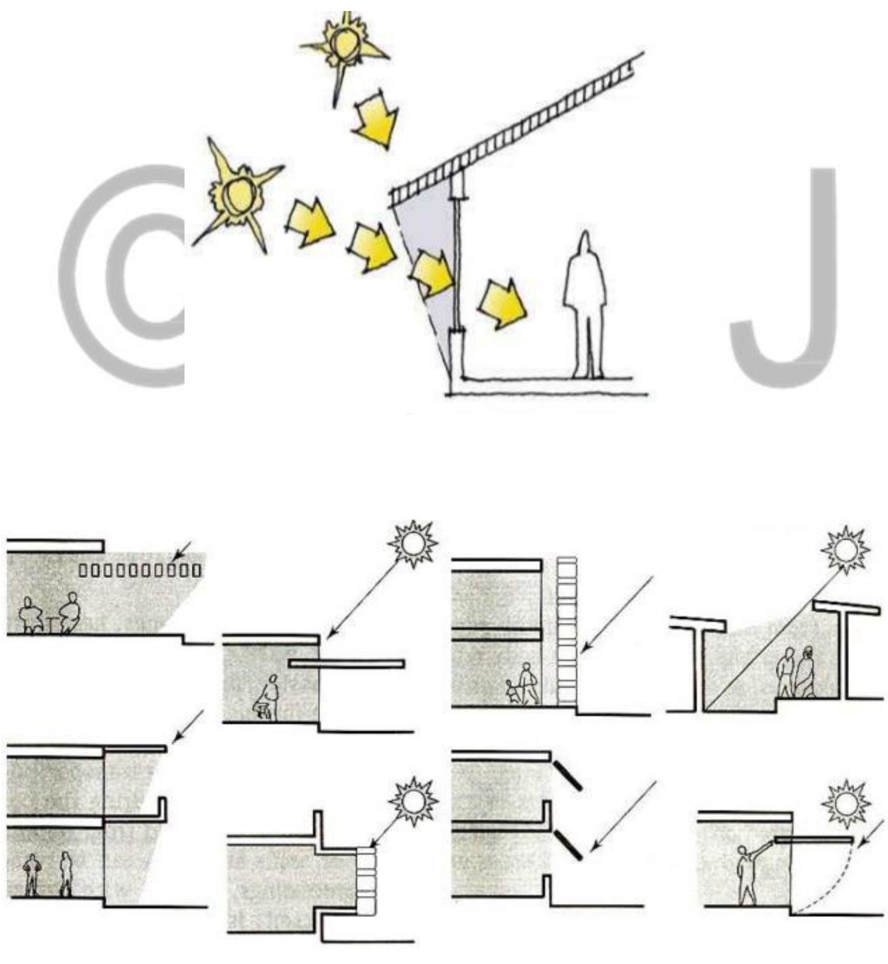

Fig. 3: Window overhangs (Source: Passive design toolkit, 2009)

4.2 Passive Design Principles for Enhancing Energy Efficiency

Passive design techniques have shown to be quite successful and may significantly contribute to reducing building cooling loads. According to Tahmina (2009), there are concepts separated into planning factors and building envelopes that aid in guiding the passive design process in order to achieve energy efficiency in a design. They are as follows:

4.2.1 Aspects of Planning:

(a) Building Form

As a result, the building forms should be wide, outwardly orientated, and not compact. Figure 4 depicts the effect of building shapes on energy efficiency. The compactness of the building reduces the surface area of the building envelope, which reduces heat gain through the envelope.

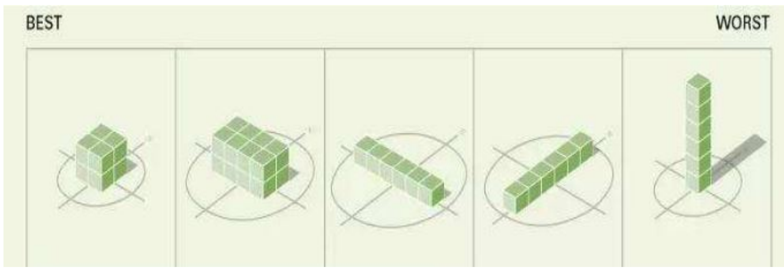

Fig. 4: Effect of building form on energy efficiency. (Source: Passive design toolkit, 2009)

(b) Building orientation

East and west-facing walls receive the most radiation, especially during hot weather. As a result, these barriers should typically be maintained as narrow as possible, with as few and small gaps as feasible. Figure 5 depicts the use of orientation to improve energy efficiency. In general, the best favored orientation is East and West facing.

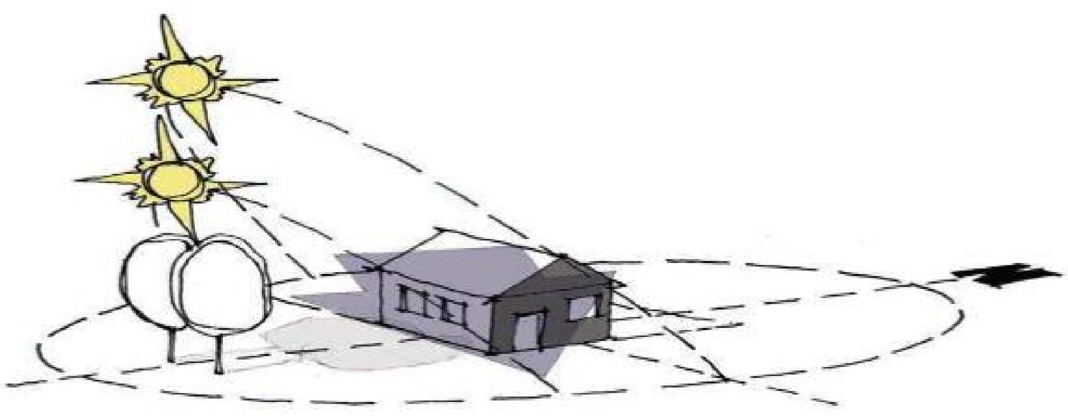

Fig. 5: Building orientation. (Source: Passive design toolkit, 2009)

(c) Spatial organization

According to Gut and Ackerknecht (1993), the organization of rooms is determined by their purpose as well as the time of day they are in use. According to Mowla (1985)'s research of spatial organization in Bangladesh, eastern facades in Dhaka get about 700 W/ m2 of morning light throughout the year. He recommends arranging rooms used later in the day on the east side, which is warm in the morning and cools off in the afternoon. According to Gut and Ackerknecht (1993), the organization of rooms is determined by their purpose as well as the time of day they are in use. According to Mowla (1985)'s research of spatial organization in Bangladesh, eastern facades in Dhaka get about 700 W/ m2 of morning light throughout the year. He recommends arranging rooms used later in the day on the east side, which is warm in the morning and cools off in the afternoon.

(d) Landscaping

Proper tree planting for energy savings finds that adequate tree planting can lower a house's cooling demands by 10% - 40%. They also point out that trees, which are better at shielding low morning and afternoon sun, can be used in conjunction with window overhangs.

Fig 6: Rockhurst University, Kansas City, Missouri, makes good use of climbers and trees to limit heat penetration into the structure. (Ogunsote,Prucnal-Ogunsote,Adegbie, 2005)

4.2.2 Building Envelope:

(a) Construction material

In Nigeria's hot-humid climatic zone, the choice of building material is critical for ensuring maximum comfort. The thermal qualities of materials that influence the rate of heat flow in and around the structure, and hence the thermal state and comfort of the inhabitants, include the following: -

- Thermal conductivity: A material's capacity to conduct heat.
- Thermal Stability: A material's ability to keep its basic physical and mechanical properties, as well as its interior structure, when heated.
- Thermal Resistance: A material's capacity to resist heat flow.
- Heat Capacity: A material's capacity to absorb heat when its temperature is raised.

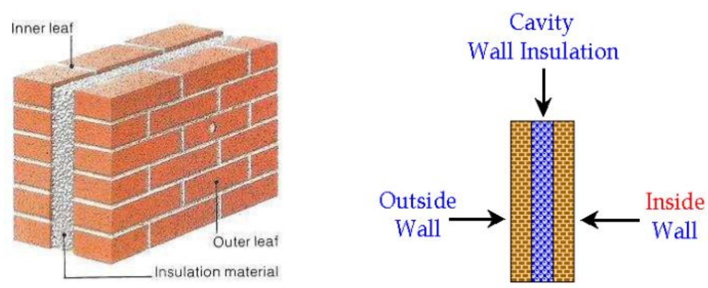

Fig. 7: Insulated brick cavity walls absorb heat thereby cooling the interior
(Source: www.smarthousingmanual.com, 2002).

The proper utilization of thermal mass throughout a structure may make a significant difference in comfort and cooling costs (Chris, 2008). This is seen in Fig. 7 with insulated brick cavity walls. Buildings in the tropics made of high thermal mass materials should be effectively shaded to prevent heat gain and inside insulated to limit heat transmission.

(b) Natural ventilation

The circulation of fresh air to replace heated air is referred to as ventilation. According to Watson and Labs (1983), ventilation serves three purposes in the construction industry. It is used to: (a) meet the inhabitants' desire for fresh air; (b) increase the rate of evaporative and sensible heat loss from the body; and (c) chill the building interior by exchanging heated indoor air for colder outside air. Cross-ventilation can also be employed to promote quicker cooling and improved ventilation, according to Givoni (1998).

"The following two forces can provide natural ventilation:

- Temperature differential between the outside and the inside of the structure
- Wind flow against the building

(c) Day lighting

Day-lighting helps to minimize the requirement for electric lighting while still contributing to bright and productive interior spaces. The amount of natural day-lighting in a room or structure is determined by the kind, size, and location of windows. Consider the sun's direction and seasonal fluctuations, the best quantity of day-light, glare reduction, and the heat gains and losses connected with the choice of windows and frames. Sunlight tubes are another means of bringing natural light into a building's interior. Sunlight tubes catch sunlight from the rooftop or outside walls, divert it down a highly reflecting shaft, and then distribute an abundance of pure day-light throughout the interior area using cutting-edge design and technology. Figure 8 depicts the utilization of sunlight tubes.

5. Conclusion

Energy efficiency, as a result of its principles and features associated to the Passive approach, suggests the employment of simple approaches and strategies that will easily generate balanced and comfortable structures. The research study is based on the premise that the energy efficiency principle may be utilized to give means that are likely to lead to discoveries in the execution of future designs and constructions employing the aforementioned passive means using design methodologies, building techniques, and material use. The adoption of such is obtained from a collection of theoretical materials that have been compiled and accessible; case studies used as inference give light on the potential inclusion of the researched problem statement. It is expected that energy-efficient solutions would be used in the design of shopping malls and other structures.

Passive design solutions have the ability to increase building energy efficiency. According to the findings of this study, lighting and ventilation are highly essential since they are primary aspects that impact the comfort of building users. A considerable proportion of users believe ventilation has the biggest influence on comfort and would want to have control over these factors. Passive design methods should be used from the beginning of a building's design process. Solar glazing and shading systems also limit solar heat gain and can enable appropriate natural light into rooms in buildings, while natural ventilation helps reduce the continual usage of artificial ventilation. These passive design solutions, when correctly implemented, may significantly increase energy efficiency in residential buildings while simultaneously lowering energy usage. Buildings should be built to offer appropriate natural lighting and ventilation while providing building users control over these variables.

This study is expected to give a model for the later implementation of Energy Efficient design principles employing passive approaches in the construction of a shopping mall or any other public structure.

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