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CONSERVATIVE METHODS OF LIGHTING AND VENTILATION IN A BUILDING: CASE STUDY, AMPHITHEATRE OF RIVERS STATE UNIVERSITY.

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ABSTRACT

The impact of natural lighting and ventilation deficiencies in buildings is a cause for concern. Findings from energy consumption research and data values, show that energy consumption in residential buildings is more from heating and ventilation, and from lighting in public buildings, with the Rivers State University's Amphitheatre falling within this category. This research therefore seeks to provide a solution that would lead to the proliferation of an energy conscious design to facilitate a sustainable architecture. The case study research approach was used as a Problem-solving method to investigate the problems associated with the Rivers State University's Amphitheatre as regards ventilation and lighting, and proffer amenable solutions to it.

The research showed that inasmuch as natural lighting and ventilation is needed for the proper functioning of building, it cannot fully meet its demand requirement, and would therefore require the combination of both natural and artificial means to ensure balance.

KEYWORDS: Indoor Air Quality (IEQ), Visual Comfort, Lighting, Ventilation

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1.0 INTRODUCTION

In today's era of thinking sustainable design, one of the objectives is to improve the impact of buildings on human health and performance. This aspect was emphasised in most green buildings' rating requirements for Indoor Environmental Quality (IEQ). It highlights four main points for achieving an improved indoor environment: Indoor air quality, acoustics, visual comfort (lighting) and thermal comfort.

Apart from sustainability in architectural design, Africa has a great need to conserve power. Hence, it is paramount to think of methods that would help conserve what little power is generated. In building design, there are important aspects that should be considered: - Lighting, indoor comfort, circulation, and in some cases acoustics. Architects and designers employ various methods to achieve designs that address the needs of the users. The methods employed are what make the difference.

The Rivers State University's Amphitheatre falls within the category of buildings that are deficient of natural lighting and ventilation, and thus would require that solutions be provided towards the proliferation of an energy conscious design to facilitate sustainable architecture, I.e. energy sustainability and conservation.

All these give rise to this research, as lighting and ventilation are both critical aspects of buildings and comfort in building spaces.

Plate 1.1: RSU Amphitheatre

SOURCE: Author (2023)

1.1 STATEMENT OF THE PROBLEM

In building design, there are important aspects that should be carefully considered; Lighting and ventilation most of all, indoor comfort, acoustics, etc. Lighting has to do with visibility in the building as ventilation does with comfort. Both are closely associated with productivity, and where this is not adequately provided, a design is deemed to have failed.

Therefore, considering the fact that the Amphitheatre is one of the most Iconic buildings in Rivers State University is a cause to ensure its maximum functionality.

2.0 LITERATURE REVIEW

2.1 ENERGY CONSUMPTION IN BUILDINGS

The energy consumption of buildings could be discussed in two perspectives i.e. narrow sense or broad sense ((Uduma, 2010). In a narrow sense, the energy consumption of a building during its operating period usually includes four sectors: space heating and cooling, household electricity, ventilation, and hot water. In general conditions, space heating and cooling will consume most of the energy and have close relation with building design. Household electricity and hot water are both independent systems, whose energy consumption depends on themselves and has less relation with architectural design. Although, because of the general lifestyle of Nigerians, lighting in building design must be considered. Mechanical ventilation consumes the least energy. Therefore, in a more narrow sense, the energy consumption of the house mainly means space heating and cooling (Akinbami, 2003).

In a broad sense, energy consumption should be discussed in the Life Cycle Analysis (LCA) perspective, which should include the energy consumption during the whole life cycle of a building, not only in its operating period, but also in material production, transportation, construction, and demolition periods. The LCA principle has been adopted in most modern environmental assessment methods, as well as energy consumption assessment. For instance, from an LCA perspective, aluminium is not recommended even if it has good physical characteristics, because of its high energy consumption in the production phase. However, less than 10% of energy is consumed in the construction phase and most of the energy is consumed in the operating phase of the building Akinbami, 2003).

The energy efficiency of buildings can be improved through Energy-efficient approaches. These measures are the ways through which the energy consumption of a building can be reduced while maintaining or improving the level of comfort in the building (Hassan, 2013).

2.2 PRINCIPLES OF ENERGY CONSCIOUS DESIGN

An energy-efficient building is designed to deliver maximum comfort to occupants by making the most of free natural heating, cooling, and lighting and utilising efficient design principles and building materials to reduce the need for appliances. According to Gulati & Paul (2013) for a building to be energy efficient it needs to have all the correct elements of design, which are listed as follows;

2.2.1 BUILDING ENVELOPE

The building envelope is the interface between the interior of the building and the outdoor environment, including the walls, roof, and foundation (Energy Land, 2016). By acting as a thermal barrier, the building envelope plays an important role in regulating interior temperatures and helps determine the amount of energy required to maintain thermal comfort (Energy Land, 2016). The building envelope can reduce the amount of energy required for cooling in the amphitheatre. (conservative methods of ventilation)

2.2.2 VEGETATION/LANDSCAPE

Shade from trees intercepts sunlight before it warms a building, and the urban forest cools the air by evapotranspiration - The process by which water is transferred from land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants. (Apollomapping, 2013).

2.2.3 SITE SELECTION

Analysis of a development site and its characteristics is a key element in the design process for maximising the use of the sun's energy, heat and light (Akadiri et al, 2012).

2.2.4 ORIENTATION OF BUILDING

Building orientation refers to the way a building is situated on a site and the positioning of windows, rooflines, and other features (Pai & Siddhartha, 2015).

2.2.5 BUILDING CONFIGURATION

The shape and surroundings of any building play a very important role in governing the energy consumption in any building, which may cause heat gain when cooling is required and heat loss when heat gain is required (Maracineanu & Bica, 2015).

2.3 CONSERVATIVE METHODS OF VENTILATION

This method does not eliminate the use of HVAC systems in building design but aids these mechanical devices such that there will be a reduction in overall energy consumption.

involves the combined use of various methods and smart home features. They include:

2.3.1 PASSIVE COOLING

Passive cooling is a design-centric method of cooling a building. It is inexpensive and environmentally safe. Some level of passive cooling is required in the amphitheatre of Rivers State University. But sadly enough, it is lacking design-wise. As cooling requirements are dictated by climate, distinctly different approaches to passive cooling are required for:

1. Hot humid climates (Zone 1) where no heating is required, also constitute the climate where the RSU amphitheatre is located.
2. Temperate and warm climates (Zones 2−6) where both heating and cooling are required
3. Cool and cold climates (Zones 7−8) where heating needs are more important

Ventilation, air exchange rates, and air conditioning should be carefully planned in all large spaces and buildings intended for gatherings. According to building codes and regulations, a minimum amount of fresh air is required per second in an occupied room. Sitting in a stuffy lecture theatre is more likely to sap your focus and promote fatigue rather than concentration. Astronomer Adam Ginsberg of the National Radio Astronomy Observatory observed and recorded this phenomenon using a portable carbon dioxide monitor at the "Linking the Milky Way and Nearby Galaxies" conference in Helsinki, (Ingraham, 2019).

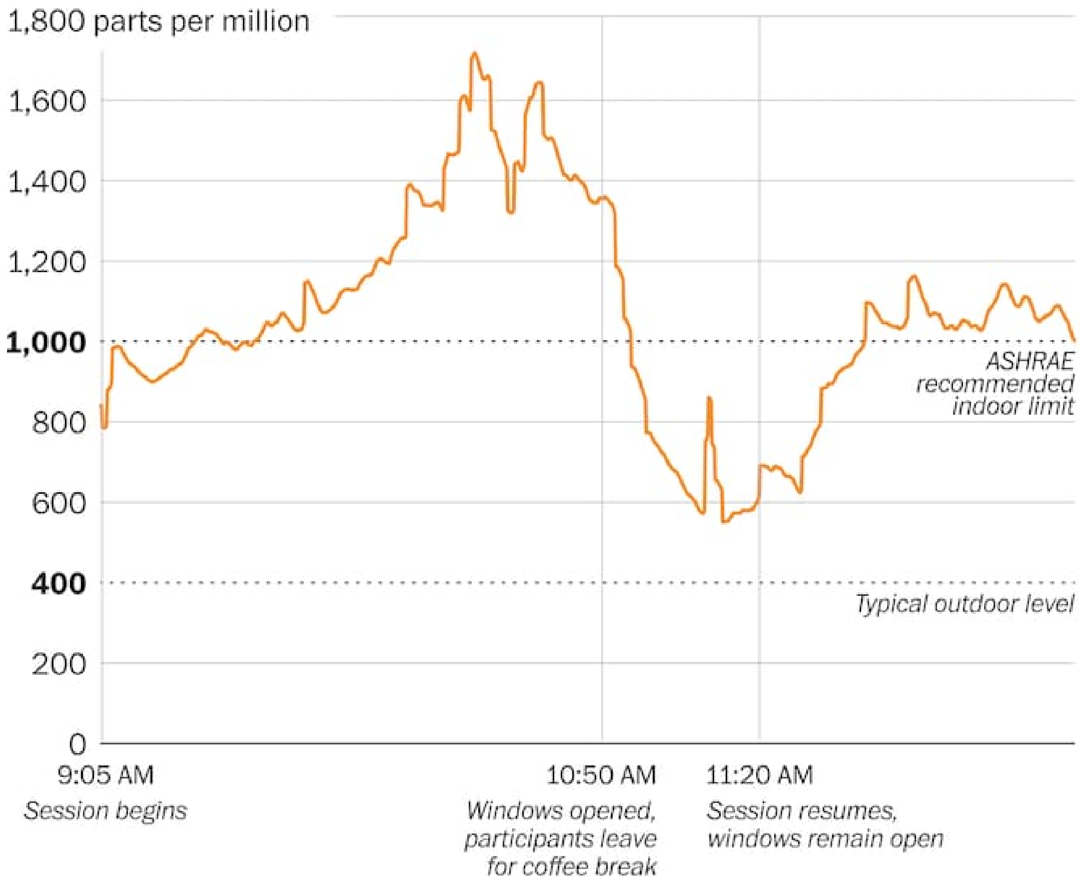

Figure 2.1: Carbon dioxide levels in an occupied conference room on June 4, 2019

SOURCE:
https://www.washingtonpost.com/business/2019/06/06/why-crowded-meetings-conference-rooms-make-you-so-so-tired/

Approximately 800 ppm of carbon dioxide was recorded, which quickly rose to 1,000 ppm. This is the threshold at which a room feels stuffy for most people, according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers. The carbon dioxide level exceeded 1,500 ppm to above 1,700 ppm. At this point, the room was emptied for a break and the windows were opened, causing the carbon dioxide levels to drop down below 600 ppm, within minutes.

The preferred system for HVAC distribution in auditoriums is a ducted supply via floor vents with ducted ceiling return vents in the auditorium and lobby. For other rooms, a ducted ceiling supply with a return air ceiling plenum is recommended with overflow ducts present in all acoustically rated partitions, (WBDG, 2017).

But in a country like Nigeria where the availability of a steady power supply is unreliable, the use and function of an HVAC system become inefficient, especially when a backup power supply is unavailable to handle its use. Passive cooling and ventilation techniques should be employed as a solution to both the challenges of climate change and shortages in the power supply.

The idea of passive cooling is to create a means for warm air to escape a building envelope, allowing for cooler air to flow around the structure.

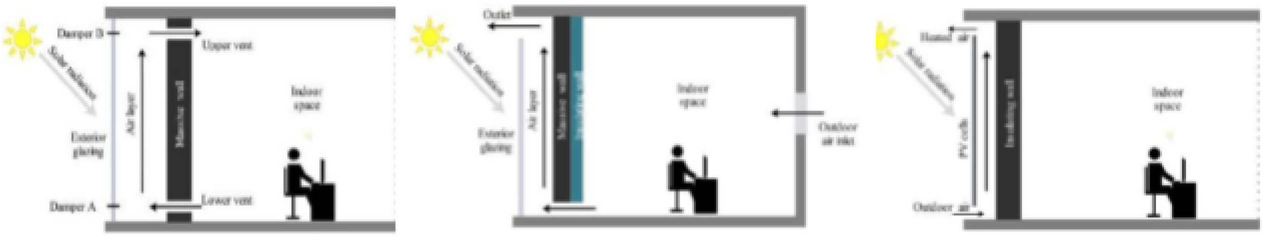

Fig 2.2a: Classic Trombe wall; Fig 2.2b: Schematic of a wall-based solar chimney; Fig 2.2c: Schematic diagram of passive ventilated PV facade

SOURCE:

In passive cooling, air movement is an important factor, which can be enhanced by the use of electronic fans regulated based on live wind speed data recorded by smart devices. This way, when there is airflow, the fans are automatically turned off, thereby preserving energy. It can also be backed with the use of air conditioners and HVAC systems.

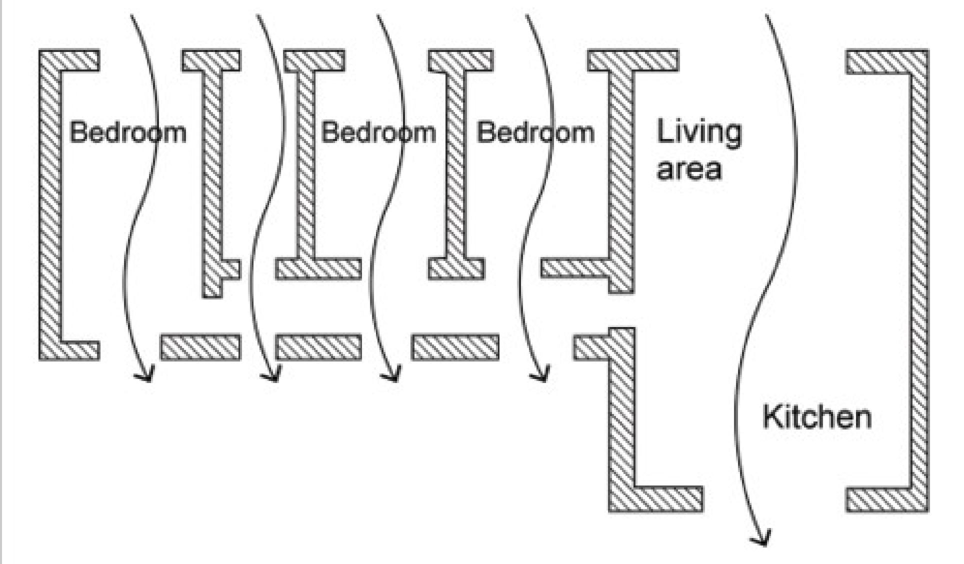

Fig 2.3: An instance of cross - ventilation for proper air movement

SOURCE: Author (2023)

There are some other conservative methods of cooling such as the various ventilation methods: - cross-flow as shown above, stack, top-down, etc. But given the magnitude of the structure, these methods will be ineffective.

2.3.1.1 VENTILATED ROOF SPACE

Well-ventilated roof spaces (and other non-habitable spaces) play a critical role in passive cooling by providing a buffer zone between internal and external spaces in the most difficult area to shade, the roof. Well-ventilated roof spaces form a buffer between internal and external areas. Ventilators can reduce the temperature difference across ceiling insulation, increasing its effectiveness by as much as 100%.

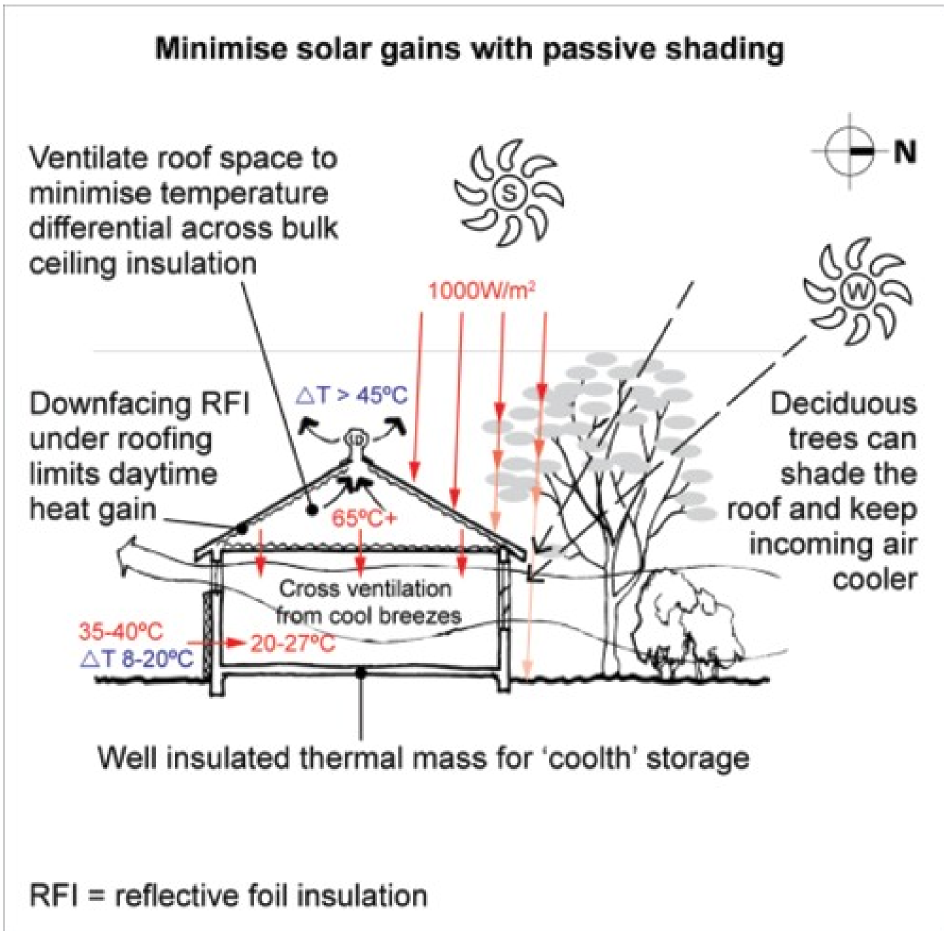

Fig 2.4: Roof space ventilation methods

SOURCE: Energy Efficiency in Nigerian Buildings: Prospects and Issues - A. Abdulsalam1, I.A. Adamu & A. M. Kofa Passive Cooling - Alishba Saleem

2.3.1.2 CLERESTORY WINDOWS

They are designed to allow for easy and efficient natural ventilation through the quick expulsion of used air in the building as a breeze comes in through the bottom vents on the leeward side of the house.

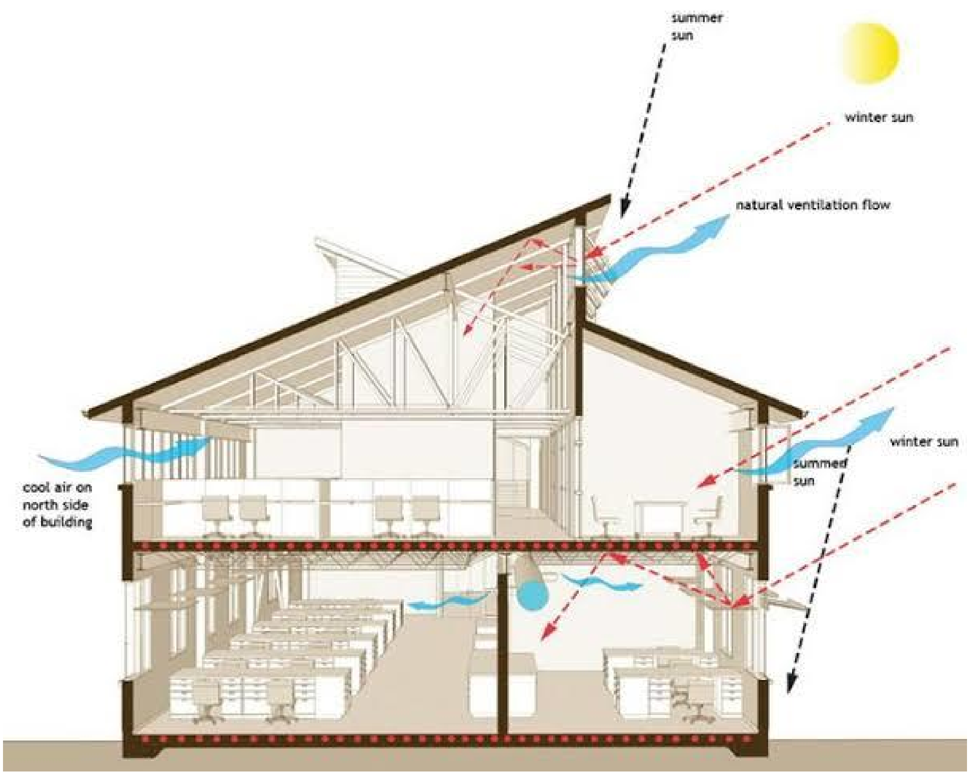

Figure 2.4: Clerestory Windows

Source: http://engineeringfeed.com/winds-impact-construction

2.3.2 EVAPORATIVE COOLING

As water evaporates it draws large amounts of heat from surrounding air. Evaporation is, therefore, an effective passive cooling method, although it works best when relative humidity is lower (70% or less during the hottest periods) as the air has a greater capacity to take up water vapour.

Pools, ponds and water features immediately outside windows or in courtyards can pre-cool air entering the house. Carefully located water features can create convective breezes. The surface area of water exposed to moving air is also important. Fountains, mist sprays and waterfalls can increase evaporation rates.

2.3.2.1 LANDSCAPING

Landscaping elements play a critical role in defining the microclimate of a site. Elements like the amount of hard paving placement of water bodies, placement of shading trees, orientation and location of building blocks etc (H. Altan et al. 2016).

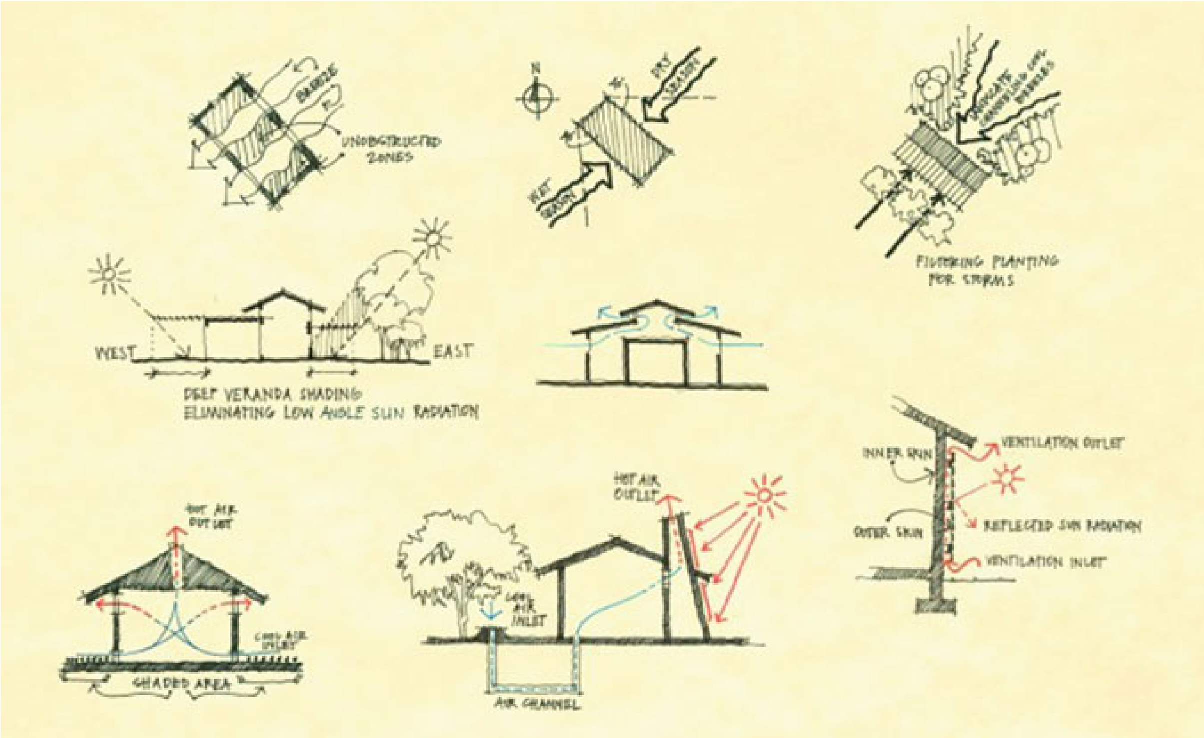

Figure 2.5: Landscaping features

Source:https://www.researchgate.net/publication/304479756_Passive_Design/link/5a0c4af1a6fdcc39e9bf5c7d/download

The amount of hard paving will affect the heat trapped around the building resulting in a heat island effect which will most likely increase the amount of cooling required in a building. Moisture from water bodies cools the environment naturally with trees and other plants acting as natural buffers and shading devices.

2.4 CONSERVATIVE METHODS OF LIGHTING

In any enclosed space, the space must be well-lit to ensure visual comfort. Especially in an event hall such as the Amphitheatre RSU. In lighting a building, natural light is preferred because it improves the productivity and comfort of occupants (Ferco, 2015), and can be introduced in ways such as:

2.4.1 CLERESTORY WINDOWS

In as much as clerestory windows serves as an easy and efficient source of natural ventilation, its design can also be used to bring in natural light into a building.

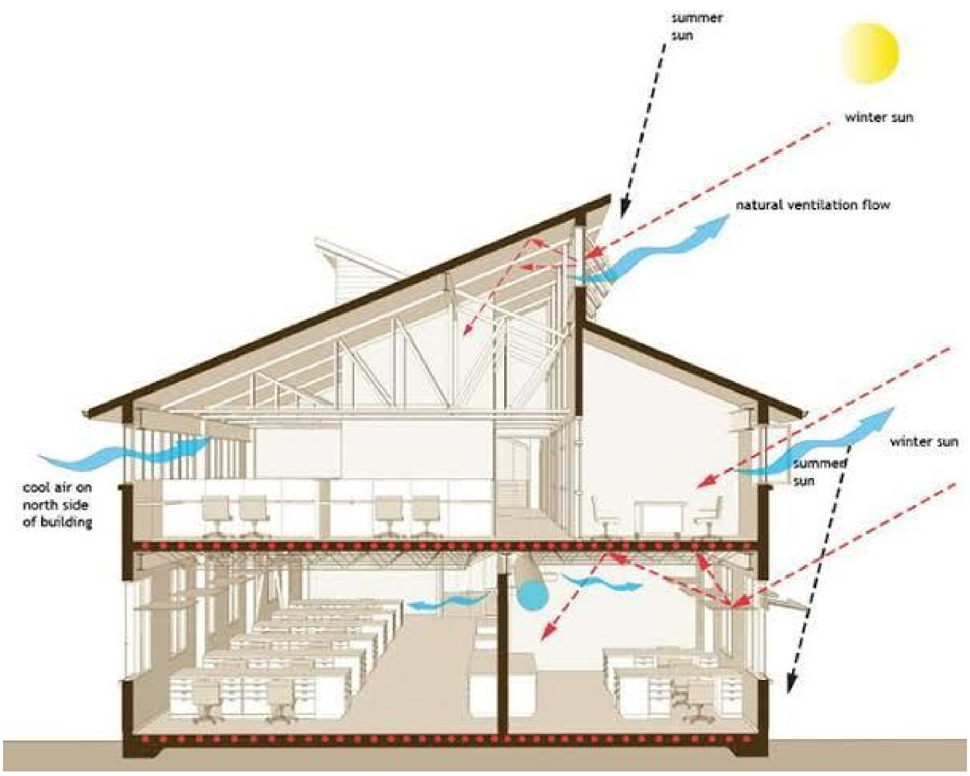

Figure 2.4: Clerestory Windows

Source: http://engineeringfeed.com/winds-impact-construction

2.4.2 SUN PORTAL: Also known as Solar Tube, and Optic Solar Cable, the Sun Portal is a mechanism that works by collecting daylight through the aid of a convex glass and conveying it via a tube with reflective properties into the internal spaces.

Figure 2.5: Floor plan and section Torrent Research Centre, Ahmadabad India

Source:
https://inhabitat.com/sunportal-uses-pipes-to-deliver-daylighting-anywhere-within-a-building/sunportal-daylighting-natural-daylight-solar-light-pipes-bender-relay/

Artificial means can also be employed, through the use of electric bulbs. Natural lighting alone is insufficient in most building designs because it is not always available in the required amount. To achieve an even more sustainable method of lighting a building, solar energy can be harnessed and stored in solar cells which can be used to boost the artificial methods of lighting with bulbs powered by these solar cells. Unfortunately, natural light can cause problems such as heat, glare as well as other complications (Ferco, 2015). But, where natural lighting is well combined with artificial lighting, energy is conserved.

2.5 RENEWABLE ENERGY SOURCES

Generating energy cleanly through solar, wind, and ocean sources represent a sustainable aspect of Passive design.

2.5.1 PHOTOVOLTAICS: It is also known as solar panels. It generates electricity from the sunlight without creating any pollution. The more intense the radiation, the more energy is generated.

3.0 RESEARCH METHODOLOGY

The case study research approach was used as a Problem-solving method to investigate the problems associated with the Rivers State University's Amphitheatre as regards ventilation and lighting, and proffer amenable solutions to it. This prompted further research on lighting and ventilation (from online publications, journals and articles) with regards to sustainability and energy conservation.

4.0 CASE STUDY

4.1 THE AMPHITHEATRE, RIVERS STATE UNIVERSITY

The design of the Amphitheatre at Rivers State University does not follow this energy-conscious design method.

Fig 4.1: Amphitheatre Building with Poor Landscaping

SOURCE: Author (2023)

From energy consumption research and data values, energy consumption in residential buildings is more from heating and ventilation (68.4%) and hot water production (lighting and appliances (14.1%) is far less significant. The poorly lit interior of the amphitheatre as well as the inoperable windows will cause the energy consumption costs to increase; AC systems and light bulbs will be used every time the building is in use.

Fig 4.2: Poorly lit interior of the RSU Amphitheatre

SOURCE: Author (2023)

4.2 CASE STUDY DEDUCTIONS

4.2.1 THE BUILDING ENVELOPE

The building envelope of the amphitheatre is not well designed. The building is not properly oriented to allow for airflow, and the exterior walls do not use any of the passive cooling methods to enhance airflow.

4.2.3 THE WINDOW DESIGNS AND PLACEMENT

The Amphitheatre is not well-lit. This is because of how the window designs have been done. To top it off, artificial lighting is poor and needs to be improved for visual comfort.

4.2.3 THE ROOFING

Amphitheatre implements a gable roof at a low pitch of about 300 slopes. The roof though is left bare without any ceiling to separate the roofing space from the building space. The result is an interior building space that is heated up and cannot be comfortable without air conditioning. The amount of energy that will be required by the HVAC system to cool the space will also be very high.

5.0 CONCLUSION

Energy resources and their utilisation intimately relate to sustainable development. A sustainable energy system may be regarded as a cost-efficient, reliable, and environmentally friendly energy system that effectively utilises local resources and networks. The research showed that inasmuch as natural lighting and ventilation is needed for the proper functioning of building, it cannot fully meet its demand requirement, and would therefore require the combination of both natural and artificial means to ensure balance. Energy efficiency in buildings has the potential to promote economic development, ensuring access to energy and can lead to job creation and saving of personal income. Adopting an energy efficiency culture will help with environmental conservation with regards gas emissions.

6.0 RECOMMENDATIONS

1. Raise the building height to allow for the provision of an insulated space that will separate the roof space from the building interior.

2. Proper landscaping and planting of vegetation

3. The use of a Photo-voltaic cells in the building's facade such that the walls can also be used to harness sunlight energy and then be used to power solar bulbs to enhance the lighting conditions of the spaces.

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