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ENERGY EFFICIENT PASSIVE DESIGN STRATEGIES IN HOT AND HUMID CLIMATE

Vaibhav Kapoor, Ar. Neelam Kushwaha

School Of Architecture

IPS Academy, Indore

ABSTRACT-Designing energy-efficient buildings in hot and humid climates can be a challenging task. The high temperatures, humidity, and intense solar radiation in these regions can result in increased energy consumption for cooling, dehumidification, and lighting. However, there are several passive design strategies that can be employed to minimize the energy consumption of buildings in hot and humid climates. This paper will discuss some of these strategies and provide case studies to illustrate their effectiveness.

PASSIVE DESIGN STRATEGIES:

Passive design strategies use natural sources of energy to reduce the energy consumed in buildings.

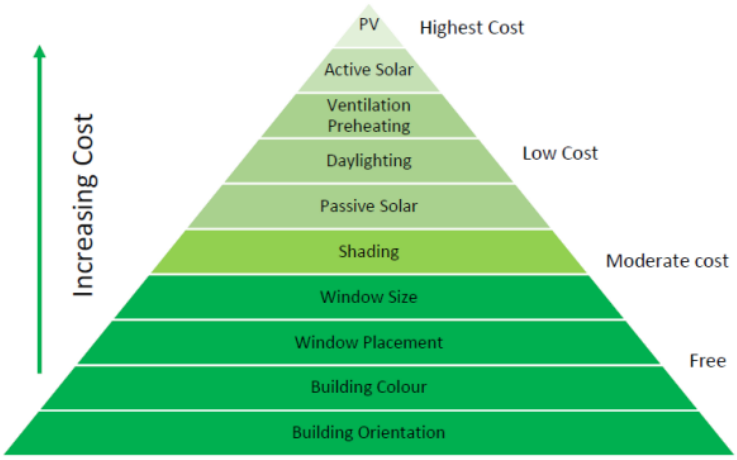

Figure 1. The solar fruit tree chart showing the free and costly strategies
Adapted from: Lechner (2014)

Lechner (2014) illustrates the energy efficient strategies in form of "A Solar Fruit Tree" stating that efficiency is the low-hanging fruit as seen in Figure 1. The "Solar Fruit Tree" shows not only all the major solar strategies, but places them at various heights in relationship to the order in which they should be picked. "Some low-hanging-fruit strategies are free or can even save money by reducing the initial cost of a building" (Lechner,2014).

In hot and humid climates, the following passive design strategies are recommended:

Orientation: The orientation of a building can significantly impact its energy consumption. Buildings that are oriented to face north-south receive less direct sunlight, reducing heat gain and cooling loads. Additionally, buildings that are oriented to take advantage of prevailing winds can benefit from natural ventilation.

Shading: The use of shading devices such as overhangs, louvers, and fins can reduce direct solar radiation on windows and walls, thus minimizing heat gain. Exterior shading devices are more effective than interior shading devices as they prevent the heat from entering the building in the first place.

Natural Ventilation: Natural ventilation can be used to cool indoor spaces by bringing in cool air from outside and exhausting warm air from the building. This strategy is most effective in regions with significant diurnal temperature swings. Building design can be optimized to encourage natural ventilation by providing operable windows and utilizing the stack effect.

Insulation: Adequate insulation can help reduce heat gain through the roof and walls of a building. This reduces the cooling load and energy consumption required to maintain a comfortable indoor temperature.

Thermal Mass: The use of thermal mass materials such as concrete and stone can help regulate indoor temperature by absorbing heat during the day and releasing it at night. This can help reduce the need for mechanical cooling systems.

Efficient Lighting: The use of energy-efficient lighting such as LEDs and CFLs can reduce lighting energy consumption. Additionally, natural day lighting can be optimized through building design to reduce the need for artificial lighting.

Research Strategy

The methods applied for the research are analytical where a review of mass housing was carried out and experimental research which involves the computer based simulation to quantify the energy consumption of the sample as well as the manipulation of the variables to evaluate the potential impact on the energy load for cooling. This method was selected as appropriate due to its characteristics of being a standard tool for conducting experiment which also reveals objective results.

Sample description

The sample selected for study is a three -bedroom bungalow which is a typical mass housing type for the average family in Nigeria. The wall construction method consists of the conventional sandcrete blocks with plaster on both sides while the roof is a pitch roof with long-span aluminum roofing sheet covering. Refer to Figures 2 and 3 for the floor plan and cross-section of the building.

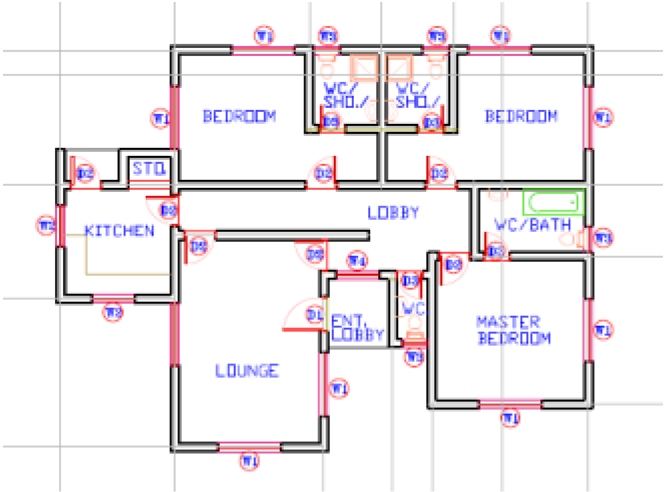

Figure 2. Floor plan- not to scale

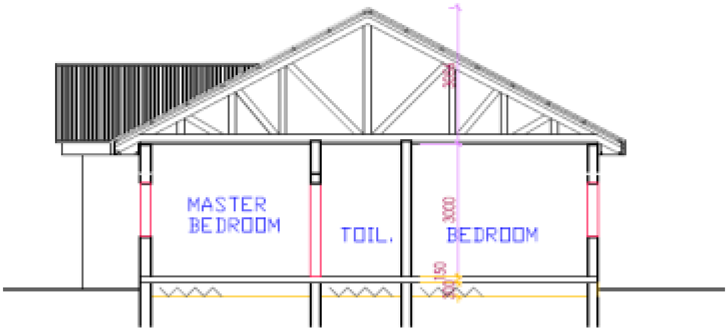

Figure 3. Cross section- not to scale

Building Simulation

Energy Plus tool was used to construct a base-case model for assessing the thermal performance of the building for a range of dynamic thermal simulations. The constant variables throughout the simulation were building activity template, occupied floor area, occupancy, air tightness and lighting (LED-3.3W/m2).

Energy Simulation of Base-Case Model

The base-case model was simulated to determine the annual energy consumption for cooling the building. The result shows the cooling load of 11245kWh. This value would be used as the base for comparison after applying the passive design measures to improve the energy efficiency of the building.

Thermal Analysis Using Passive Design Strategies

The strategies for heat avoidance were used with the aim of investigating the effect of employing free to low cost strategies on the energy consumption for cooling the building. The elements were selected based on passive design strategies suitable for the tropical climate of Abuja. Before applying these strategies, the walls were replaced with a sustainable alternative. Compressed Earth Bricks was proposed to be used in place of the sandcrete blocks due to its cost effectiveness and better thermal properties. A reduction in cooling load of 8% was achieved.

Orientation

The model was analyzed with the façade facing different orientations in where the North facing gave the least amount of cooling load. This gave a cumulative reduction of 12%.

Color

The review of literature reveals that by simply changing the roof colour from red to reduces heat gain into the building. The simulation results gave a lower roof temperature by approximately 3oC. A further cumulative reduction in cooling load of 16% was achieved.

Window to Wall Ratio(WWR)

To reduce the effect of direct solar radiation, the east and west facing windows were reduced while increasing the size of the north facing windows to let in cool air. These changes resulted in overall lower window to wall ratio from 24.8% to 21.4%. A cumulative reduction in cooling load of 19% was achieved.

Shading

Shading is not free but cost effective due to the amount of reduction in cooling load achieved. An extension of roof overhang was proposed as the most suitable low cost strategy for shading the windows in this analysis. A depth of 1070mm was calculated to shade the whole window but a depth of 1100mm was used to further shade part of the walls below the window sill. In addition, venetian blind was added to the outside of the east and west facing windows. This resulted in a cumulative reduction in cooling load of 30%.

CASE STUDIES:

1.National University of Singapore (NUS) school of design and environment:

The NUS School of Design and Environment is a green building that utilizes several passive design strategies to minimize energy consumption. The building is oriented north-south to reduce heat gain and take advantage of prevailing winds. Exterior shading devices such as fins and overhangs are used to minimize direct solar radiation on windows and walls. Additionally, the building has a green roof that helps reduce heat gain and improve thermal comfort.

2. Dau1 emu Cyprus

The following energy efficient architectural features check-list is used in the assessment of DAU 1 EMU Cyprus

(i) Building envelope

(ii) Natural lighting

(iii) Natural ventilation

(IV) Landscape design

(v) Building orientation

(VI)Building form

S.No.	VARIABLE	CHECKLIST	LEVEL OF APPLICATION			
			ABSENT	LOW	AVERAGE	HIGH
1	Building Envelope	Suitability of the materials to the climate			Y	
		Use of external insulation		Y		
		Use of light colours				Y
2	Natural Lighting	Wall to window ratio (40%)			Y	
		Use of specially transparent glass			Y	
3	Natural Ventilation	Use of openable windows			Y	
4	Landscape Design	Use of soft landscape			Y	
		Use of hard landscape		Y		
5	Building Orientation	Sun Orientation (East -West)			Y	
		Wind Orientation (South-West - North-East)			Y	
6	Building Form	Large building surface area		Y		

CONCLUSION:

As we study above data, it is conclude that passive design strategies are very useful in building sector because of this no toxic gases release in the environment. The key to Designing a passive building is to take advantage of the micro-climate.

In recognition of the impact of climate change on the environment, this study investigated the effect of low cost passive design strategies on the energy efficiency. From the cases studied in DAU1 EMU Cyprus, it is apparent that much still need to be done in applying the concept of passive design principles in enhancing energy efficiency in university dormitory.

This research reveals that heat avoidance is the first and most important passive strategy for energy efficient buildings. These were best achieved by picking the 'lowest hanging fruit' i.e. beginning with the simple and free strategies before reaching the costly ones.

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