Integration of Passive Energy Efficient Design Elements for Office Complex, Abuja, Nigeria

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Abstract:
Energy necessity of buildings has seen an increase over the past years. Predominantly is the demand for cooling and lighting of buildings. The commercial sector has been identified as one of the major contributors to the immense diminishing of natural resources through the use of artificial energy for cooling and lighting of buildings. The study integrates passive energy efficient design elements to achieve sustainable energy efficient office buildings in Abuja, Nigeria. The research adopted descriptive survey method as it permits for multi-dimensional approach to data collection. Qualitatively, the extent at which passive design elements such as building orientation, courtyard, building form, thermal insulation, and skylight have enhanced energy efficiency was determined. Through stratified random sampling, ten (10) office buildings were selected across the city of Abuja to observe the energy efficient design elements adopted in them. Data was collected through observation schedule and well-structured questionnaire. Data collected was statically analyzed and the result showed that office buildings in Abuja were designed with little consideration for passive design elements as most of the office buildings depend on mechanical means for lighting and cooling. It is recommended that passive design elements should be considered in future office design to reduce energy requirements and the negative effects it might have on the environment.

Keywords: design strategies, Energy efficiency, Office buildings, Passive cooling, and Passive lighting.

INTRODUCTION

Energy required by buildings has seen an upsurge over the past decades, predominantly is the energy demand for lighting and cooling of buildings. The artificial means used for improving energy needs of buildings lack credibility in terms environmental sustainability (Hyde, 2017). Passive design elements such as orientation and form of the building, radiant heat transfer, evaporative cooling, can be used to attain energy efficiency in buildings (Gokarakonda, and Kumar, 2016). These means have passed the conditions for sustainability. Reduced environmental impact and resource intake are some of the advantages linked to these passive energy efficient strategies (Peter, 2015). Bassler *et al.* (2015) identified that energy saving is locally designing for energy management which aims to curtail the use of conventionally driven ventilation, heating, and lighting by complementing natural energy obtainable at the building site. In tropical areas like Abuja, the major usage of energy in office buildings is for ventilating, lighting and running services such as lifts operation, refrigeration and office equipment. Embracing passive strategies will lead to reduced energy required by the buildings.

Passive cooling can be attained through numerous design methods such as the use of sun shading devices, courtyards, laminated windows, and landscaping. Courtyards also function efficiently in lighting interior areas. Sky lights and large openings are other inactive means of achieving day lighting in buildings (Anink et al, 2010). The word office can be seen as any building that fits into

a suitably zoned unit, block and lot as recognized by statutory authorities for commercial purpose. The concept of an office differs, but best characterized by the building design guides by what spaces it encloses. According to WBDG (2009), a characteristic office space may include an office work space, integrated meeting space, work rooms, core office support space, storage rooms, file rooms, mail rooms, conferences, copy areas, telephone, mechanical and communication equipment rooms, fitness, store, cafeteria, childcare, packing.

Commercial buildings like office buildings have been recognized as one of the main contributors to the decreasing ecological resources (Lam *et al.*, 2011). Researches show that office buildings account for a significant amount of energy consumed by buildings in many parts of the world including Abuja. This energy consumption if not tamed can lead to global warming through the release of harmful gases like greenhouse gas into the environment. Dependence on mechanical means of lighting and cooling office buildings have generated numerous environmental challenges (Oyewunmi, 2016). This study is aimed at integrating energy efficient design strategies to provide eco-friendly office buildings in Abuja, Nigeria.

The Concept of Passive Design Strategies

Following the rise in awareness about global heating and the reliance of built environment on energy for everyday activities, sustainability is progressively being stressed around the world. Occupants of buildings are now more aware of the significance of sustainability for an improved quality of life (Sambo et al, 2014). Energy is necessary for buildings' activities. Lighting, ventilation, insulation, and controls have been enhanced and these are significant features to achieve energy efficiency. Energy efficient Passive design strategies, such as thermal mass, cross ventilation, external shading, building orientation, and insulation in buildings, are the components of sustainable building (Wimmer et al, 2013).

Passive Design Strategies

Passive Design refers to actions put in place to create a building by means of natural movement of heat and air in order to preserve a good internal environment (Gokarakonda, and Kumar, 2016). Passive design includes collection, storage, and distribution of energy movement through natural means. The main objective of passive design is to lessen or remove the need for active motorized systems while preserving occupants comfort (Hyde, 2018). Some of the passive design strategies are discussed below.

Passive design by orientation refers to how a building is positioned on site to take benefit of climatic features (McGee, 2013). West and east facing walls get the highest amounts of radiation. The best form and orientation in the tropics is rectangular with the long axis running east-west to curtail solar heat gain (Yamba, 2013). In addition, Overhangs and shadings aid in curbing overheating (Tin – Tai, 2017). They should be correctly sized on the building facade to ensure suitable shading.

Buildings need to be sufficiently insulated in order to hold heat in winter and keep the cool throughout summer. Insulated materials are bad conductors of heat, they also form a barrier between interior and exterior spaces, and serve to preserve warmth in cold season between interior and exterior (Santamouris, 2007). More so, windows and doors have significant functions in allowing in natural light and air. However, in the tropics, they are the main causes of unwanted

heat gain (McGee, 2013). The perfect design would have only south and north windows and fewer or no east or west windows (Lechner, 2014).

Also, evaporative cooling reduces indoor air temperature through evaporating water. In dry climates, this is usually done directly in the space. But indirect approaches, such as roof pools, permit evaporative cooling to be used in more temperate climates. Ventilation and evaporative cooling are often complemented with mechanical methods, such as Air conditioners. They use noticeably less energy to preserve comfort when compared with refrigeration systems (Brown and Dekay, 2011).

In summary, consumption of energy is a vital element of development. While energy use obviously has numerous benefits which include; reduced Life-cycle Costs (Pitts, 2017), minimized resource consumption (NCR, 2015, Francis et al, 2011), lessened environmental effect (IEA, 2018), improved indoor environment (Young et al., 2015), emissions and health benefits (U.S. EPA, 2017), we are also becoming progressively conscious of the negative effects of energy use (Yamba, 2016). We experience these bad effects universally and locally in the form of poor air quality, climate change and degradation of soils.

METHODOLOGY

The descriptive method of survey was adopted in carrying out this research. This is because it allows for detailed information which permits for many-sided approach to data gathering and examination. This method was used to assess design strategies for energy efficiency in office buildings. The main passive design elements examined include day lighting, evaporative cooling, building form, natural ventilation, orientation, landscaping and thermal mass. An investigation was done on the office buildings examined to determine the degree to which passive cooling and lighting building elements were adopted in their designs, and also to examine how satisfied or dissatisfied the occupants of the buildings are with the passive elements used. This examination was done through critical observation and post occupancy evaluation of the design elements adopted in the design of the sampled office buildings.

Qualitatively, users' perception was analysed through post occupancy evaluation and with the aid of questionnaire. These were used to determine their level of satisfaction with energy efficient design elements adopted, these elements includes; courtyard sizes, windows opening sizes, quality of natural lighting and ventilation, and orientation of the buildings. Direct observation through the use of an observation schedule was done on the sampled office buildings to determine whether passive design elements such as evaporative cooling, courtyard, skylight used were adopted appropriately and in good proportion.

Stratified random sampling was employed. This divides the population into smaller strata based on shared characteristics. High rise office buildings were selected due to their extended need. Ten office buildings were selected across Abuja city. SPSS was used to scrutinize the data derived from the questionnaires and observation schedules. Likert scale was used to examine the users' perception of the energy efficient elements used on the sampled buildings.

DATA ANALYSIS

Here, the results of the analysis of data collected are presented. These results and consequences are presented based on the goal drawn in the introductory part of the research work.

Building form for energy efficiency

The form of a building has effect on the energy required by the building. In the tropics where reduction of the effect of the heat on buildings is a major design concern, rectangular forms are encouraged. The impact of the sun on the buildings is minimized as such, they require less energy when compared to circular and oval forms. As shown in figure 4.1, 90% of the office buildings studied were rectangular in shape, as such the effect of the sun on the buildings is concentrated on one side of the buildings and making the other sides to keep their cool. 10% of the sampled buildings are circular and oval shaped this has effect on the building because the sun acting on the building tends to spread round the building due to the shape and therefore making all building sides to be exposed to sunlight, leading to non-efficiency of energy.

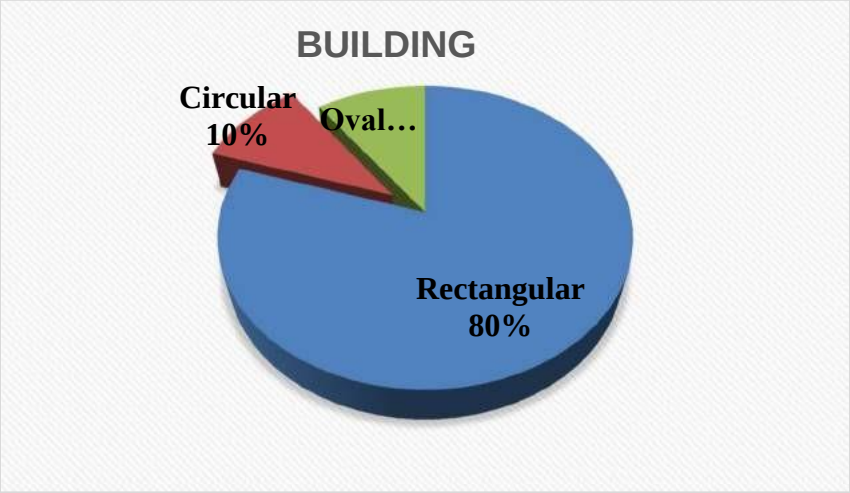

Figure 1: present the form of office buildings in Abuja.
Source: Researcher's fieldwork, 2019.

Building orientation towards energy efficiency

A key factor of the impact of the sun on a building is orientation. Another key determinant of the impact of the sun on a building is its orientation. How buildings are positioned on site with regards to the position and path of the sun have direct impact on the amount of heat the building receives during the day. To minimize heat, it is encouraged that the longer parts of the building do not face the east or west directions. Sun rises from the east and sets in the west. Its effect is felt more along that path. Table1 shows the positioning of the sampled office buildings on site. It is observed that most of the office buildings examined are oriented properly with the longer side facing the north-south direction and having larger windows while the west-east side of the buildings have shorter sides with smaller windows to reduce the effect of sunlight on the buildings. Only a few do not conform to this, as such do not obey to lessen heat gain.

Table 1: Orientation of Office Buildings.

S/N	Name of building	Orientation with respect to sun rise and sun set	Position of building on site
01	NNPC Towers	North-West	Obeys to lessen heat gain
02	Churchgate	North-South	Obeys to lessen heat gain
03	Metro Plaza	North-South	Conforms to cut heat gain
04	Bank of Industry	East-West	Does not follow to cut heat gain
05	World Trade Centre	North-South	Follows to cut heat gain
06	IGI building	North-South	Follows to decrease heat gain
07	FIRS Building	North-South	Conforms to decrease heat gain
08	NCC Building	North-South	Obeys to lessen heat gain
09	ITF House	North-South	Conforms to lessen heat gain
10	FERMA Building	North-South	Follows to decrease heat gain

Source: Authors' Fieldwork, 2019.

Table 1 shows that all the buildings studied except Bank of Industry are oriented to North-South to decrease the quantity of heat on the building.

Landscape elements from the sampled buildings

Introduction of flora in the design of environments and building surroundings help to prevent solar radiation and improve temperature regulation. According to figure 4.3, the main element employed in the sampled buildings was shrubs, trees and ground covers. Water, shrubs and trees have been used to cool the buildings examined, though these landscape elements are good but were not used appropriately. 5% of the sampled office buildings have made use of water for cooling the building; about 39% of the buildings have used ground covers while 24% used trees to keep the environment cool. In summary, the landscape elements adopted are not used in their sufficient amount and thereby are not energy efficiency.

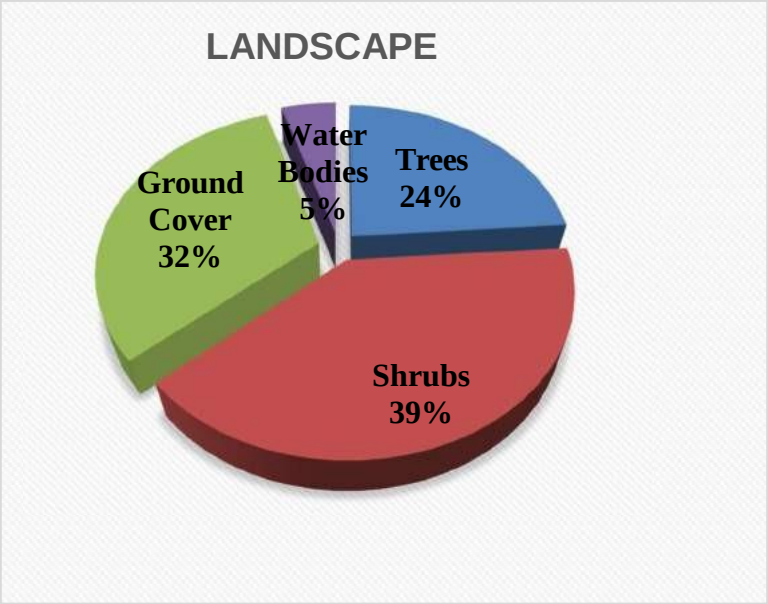

Figure 2: Soft Landscape Elements used in the case study buildings.
Source: Authors' Fieldwork, 2019.

Energy efficient natural ventilation

This is significantly influenced by the size and positioning of openings in a building. According to Figure 2, it was observed that most of the buildings adopted operable window on glazed walls which allows also for maximum lighting but have effect on the heat gain of the buildings. Courtyard was also adopted in some of the buildings to cater for lighting of the interior spaces.

The windows used sum to 56% of the total wall area which is adequate enough for effective ventilation. 50% of the buildings studied can be ventilated naturally, though they are supplemented with artificial ventilation.

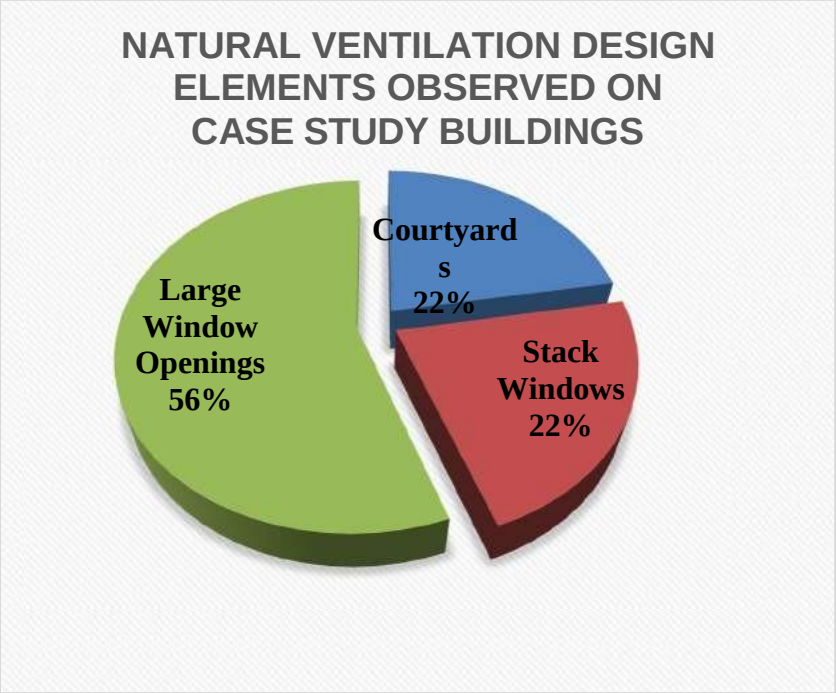

Figure 3: Natural Ventilation design elements used in the case study buildings.
Source: Authors' Fieldwork, 2019

Occupant satisfaction evaluation in office buildings, Abuja

Questionnaire was disseminated to occupants and staff of the sampled buildings. The following data was collected and analysed.

The 4 – Likert scale measurement was used to scrutinize the perception of the users of the office buildings. A score scale of 1 – 4 was used to test the respondents as stated below:

Very Dissatisfied (VD) 1
Dissatisfied (D) 2
Satisfied (S) 3
Very Satisfied (VS) 4

Table 2: Number of respondents per opinion on satisfaction level with Passive energy efficiency design elements.

Key	Variable	Very Dissatisfied		Dissatisfied		Satisfied		Very Satisfied		Total
			%		%		%		%	
Lp01	Position of building relative to sun movement.	24	11.5	33	15.8	62	29.7	90	43.1	209
Lp02	shading devices	53	25.4	88	42.1	46	22.0	22	10.5	209
Lp03	Natural ventilation	39	18.7	81	38.6	63	30.1	26	12.4	209
Lp04	Natural lighting	32	15.3	45	21.5	63	30.2	75	35.9	209

Lp05	Openings sizes	25	12.0	39	18.7	102	49.0	43	20.6	209
Lop6	Size of interior spaces	50	23.9	76	36.4	44	21.1	39	18.7	209
Lp07	Size of exterior open spaces	47	22.5	81	38.8	36	17.2	45	21.5	209
Lp08	Amount of vegetation	82	39.2	74	35.4	41	19.6	12	5.7	209

Source: Authors' fieldwork, 2019

Multiplying the number of respondent in each section by the given score it gives the total in 3 below.

Table 3: Sum and interpretation of occupants satisfaction level with Passive energy efficient design elements.

Key	Variable	VD (X1)	D (X2)	S (X3)	VS (X4)	Sum	Mean	Interpretation
Lp01	Position of building relative to movement of the sun.	24	66	186	360	636	3.04	Satisfied
Lp02	Sun shading devices	53	176	138	88	455	2.2	Dissatisfied
Lp03	Natural ventilation	39	162	189	104	494	2.36	Dissatisfied
Lp04	Natural lighting	32	90	189	300	611	2.92	Satisfied
Lp05	Size of Window Openings	25	78	306	172	581	2.77	Satisfied
Lop6	Size of interior spaces	50	152	132	156	490	2.34	Dissatisfied
Lp07	Size of exterior open spaces	47	162	108	180	497	2.37	Dissatisfied
Lp08	Amount of vegetation	82	148	123	48	401	1.91	Dissatisfied

Source: Authors' Fieldwork, 2019

The results interpretation based on 4-Likert scale are as follows:

1.0 - 1.49 Very Dissatisfied
1.5 - 2.49 Dissatisfied
2.5 - 3.49 Satisfied
Above 3.5 Very Satisfied

As deducted from Table 3, majority of the respondents are contented with the placing of the buildings, natural lighting and the size of openings. However, they expressed displeasure with the other variables which include size of interior spaces, sun shading devices, natural ventilation. Amount of vegetation records the lowest satisfaction level. They were mostly satisfied with the position of the building with regards to movement of the sun. This implies that sun shading devices, amount of vegetation natural ventilation, need to be improved upon.

FINDINGS

The analysis showed that designers do not properly integrate passive design elements in office buildings design due to the non-functionality of the ones studied in the sampled buildings

About 36% of office buildings have adopted these passive design elements. However due to their inappropriateness, they are complemented with other sources of energy which are harmful to the environment.

It is discovered that some office buildings in Abuja require large energy for cooling and lighting due to the fact that the passive design elements were not adopted in their designs. However, these energies have negative effects on the environment.

CONCLUSIONS

The concept of passive energy design proposes using design strategies to decrease reliance on artificial. As analysed, it was noticed that the occupants of the sampled office buildings were displeased with most of the energy efficient elements adopted in the buildings. They were mostly dissatisfied with the vegetation and other landscape elements. Sun shading devices recorded low score value. Passive cooling elements used comprised laminated window, overhangs, shading devices and interior gardens. 56% of the buildings observed used large windows, 22% used courtyards and 22% adopted stack windows for lighting and ventilation.

It is recommended that designers and developers in the built environment should clinch to passive design strategies to reduce reliance on artificial means. Also stakeholders in the built environment should provide awards for designers who design outstanding sustainable buildings.

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