Architectural Features of Building in Relation to Effectiveness of Natural Ventilation

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ABSTRACT

The objective of the study was to examine the architectural features of the building in relation to effectiveness of natural ventilation for middle income residential houses in Uyo Metropolis., Akwa Ibom State. Descriptive survey research design was used for the study. The population for the study consisted all middle income housing in Uyo metropolis. The instruments used for data collection were liquid crystal thermometers, wet and dry bulb hygrometer, anemometer, questionnaire and the CBE Thermal Comfort Tool (a computer model programme). The instrument was face and content validated by expert from test, measurement and evaluation while Crombach Alpha technique was used to determine the reliability of the instrument at 0.84 coefficient. Data obtained were analysed using Pearson Product Moment analysis. The findings of the study revealed that there is significant relationship between architectural features of the building and the effectiveness of natural ventilation and thermal comfort. It was recommended among others that buildings should be orientated with their longer sides intercepting prevailing winds and the shorter sides facing the direction of the strongest solar radiation. This will help avoid heat stress in the building.

Key Words: architectural features, Thermal comfort, ventilation

Introduction

Natural ventilation is clearly a valuable tool for sustainable development as it relies only on natural air movement, and can save significant amount of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning. Reducing electrical energy used for cooling contributes to the reduction of greenhouse gas emissions from the electrical generating plant providing the energy (Aynsley, 2007). If a building is to provide acceptable thermal comfort conditions passively without the use of mechanical systems then certain considerations has to be made in the design of such building. These considerations must apply to complete rooms, not just to the elements comprising the structure. By focusing on the performance expected from the system as a whole, roof, walls, floors, and their connections, as well as climatic variables in the area, problems may be identified and avoided at the outset. Optimum application of these considerations is the key to deriving maximum thermal comfort benefit from the house when put to use.

The first step in planning for the design of a passive ventilated building is by determining the local wind and breeze patterns in the site. This, according to Janderson (2015), could be achieved by getting summary information from the local weather information service. Annual prevailing winds for the site are summarized in a wind rose or similar wind diagram (Figure 2.9) to see the side to take advantage of or avoid. It is crucial for a designer to be able to exploit that sea breeze or regular breeze in the afternoon and be able to eliminate the heat that builds up in the home during the day. Other considerations are: good orientation of the building on site, buildings do not have to face directly into the wind to achieve good cross-ventilation but internal spaces and structural elements can be designed to channel air through the building in different directions; building site surroundings, wind access and sheltering; site massing and orientation, etc. all the design strategies put together effectively can minimize the need for a mechanical ventilation.

Objective of the Study

The objective of the study is to examine the architectural features of the building in relation to effectiveness of natural ventilation for middle income residential houses in Uyo metropolis.

Research Hypothesis

To achieve the objective of the study, the null hypothesis will be tested:

H_O: There is no significant relationship between architectural features of the building and the level of effectiveness of natural ventilation in the study area.

H_1: There is significant relationship between architectural features of the building and the level of effectiveness of natural ventilation in the study area.

Statement of Research Problems

Achieving thermal comfort through passive means in hot humid climates is not always easy. Characterized by relatively high temperature and high humidity, these climates usually require both cooling and dehumidification. These difficulties lead to many buildings relying completely on air-conditioning. Nevertheless, a range of passive design techniques may be employed to help minimize or avoid this reliance.

Review of Related Literature

Theory of Architecture

According to Evers and Thoenes (2003), architectural theory is the act of thinking, discussing, and writing about architecture. Architectural theory is taught in most schools of architecture and is practiced by the world's leading architects. It takes some forms like lecture or dialogue, treatise or book, and paper project or competition entry. Architectural theory is often didactic, and theorists tend to stay close to or work from within schools. It has existed in some form since antiquity, and it publishing became more common, architectural theory gained an increased richness. Books, magazines, and journals published an unprecedented amount of works by architects and critics in the 20th century. As a result, styles and movements formed and dissolved much more quickly than the relatively enduring modes in earlier history. There is little information or evidence about major architectural theory in antiquity, until the 1st century BCE, with the work of Vitruvius. This does not mean, however, that such works did not exist. Many works never survived antiquity (Kruft, 1994).

Evers *et al* (2003) is of the opinion that throughout the Middle Ages, architectural knowledge was passed by transcription, word of mouth and technically in master builders' lodges. Due to the laborious nature of transcription, few examples of architectural theory were penned in this time period. Most works from this period were theological, and were transcriptions of the bible, so the architectural theories were the notes on structures included therein. The Abbot Suger's *Liber de rebus in administratione sua gestis*, was an architectural document that emerged with gothic architecture. Another was Villard de Honnecourt's portfolio of drawings from about the 1230s. According to Ssu-ch'eng, (1984), in Song Dynasty China, Li Jie published the *Yingzao Fashi* in 1103, which was an architectural treatise that codified elements of Chinese architecture Ssu-ch'eng. The first great work of architectural theory of Renaissance period belongs to Leon Battista Alberti, *De Re Aedificatoria*, which placed Vitruvius at the core of the most profound theoretical tradition of the modern ages. From Alberti, good architecture is validated through the Vitruvian triad, which defines its purpose. This triplet conserved all its validity until the 19th century. A major transition into the 17th century and ultimately to the phase of Enlightenment was secured through the advanced mathematical and optical research of the celebrated architect and geometer Girard Desargues, with an emphasis on his studies on perspective and projective geometry (Salingaros, 2006).

The Age of the Enlightenment witnessed considerable development in architectural theory on the European continent. New archeological discoveries (such as those of Pompeii and Herculaneum) drove new interest in Classical art and architecture. Thus the term Neoclassicism arose to designate 18th-century architecture which looked to these new classical precedents for inspiration in building design (Middleton and Watskin, 1980; Bergdoll, 2000). In contemporary architectural discourse theory has become more concerned with its position within culture generally, and thought in particular. This is why university courses on architecture theory may often spend just as much time discussing philosophy and cultural studies as buildings, and why advanced postgraduate research and doctoral dissertations focus on philosophical topics in connection with architectural humanities. In the past decade, there has been the emergence of the so-called "Digital" Architecture. Several currents and design methodologies are being developed simultaneously, some of which reinforce each other whereas others work in opposition. One of these trends is Biomimicry, which is the process of examining nature, its models, systems, processes, and elements to emulate or take inspiration from in order to solve human problems, (Nesbitt, 1996).

Internal Spaces and Structural Element

Poorly designed homes with internal walls and barriers to cross-ventilation will have stagnant stuffy hot-spots that may require exhaust fans. Internal walls should be orientated to allow for cross-ventilation (Figures 1.1). If internal walls act as barriers, in as much as possible the designer should try to have the top open or vents to allow for air flow. This will allow some cross-ventilation and exhausting of the hotter air that rises and accumulates below the ceiling. Where walls are fixed, permeable walls such as adjustable timber louvres, lattice, wide double doors, or other alternatives should be introduced to allow for air movement. The avoidance of placement of structures like carports, garages, sheds and other structures where they will tend to block the prevailing breezes will aid the achievement of passive ventilation of the internal spaces.

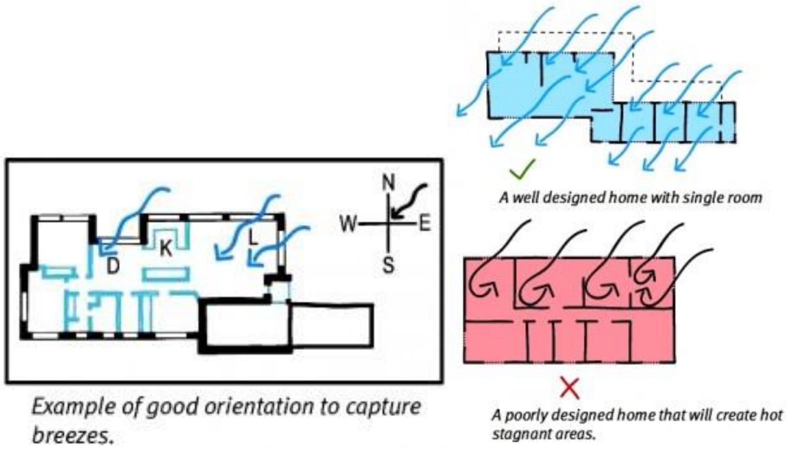


Fig. 1.1: *Orientation of internal walls for cross ventilation*
Source: DeKay and Brown (2001)

Architectural features can scoop air into a room. Such structures facing opposite directions on opposite walls can heighten this effect. These features can range from casement windows or baffles to large-scale structures such as fences, walls, or hedgerows (Figure 1.2).

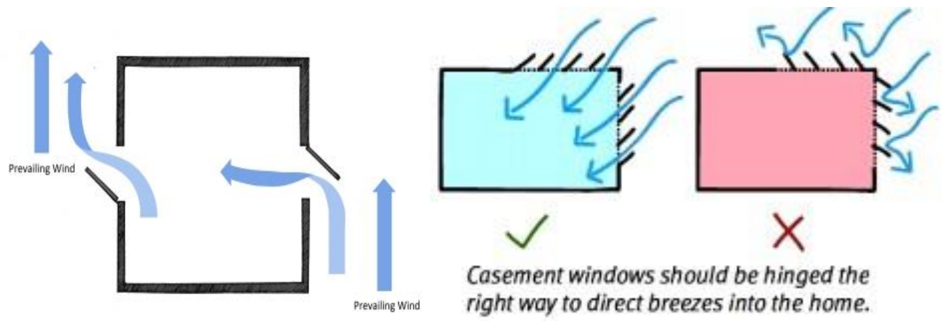


Fig. 1.2: *Building structures can redirect prevailing winds to cross-ventilation*
Source: *Autodesk Education Community, (2015)*

Wing walls project outward next to a window, so that even a slight breeze against the wall creates a high pressure zone on one side and low on the other. The pressure differential draws outdoor air in through one open window and out the adjacent one. Wing walls are especially effective on sites with low outdoor air velocity and variable wind directions (Figure 1.3).

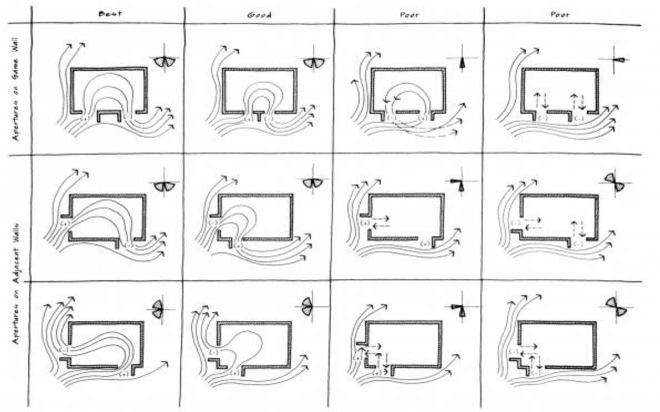


Fig. 1.3: *Different wing walls of better and worse effectiveness, on same wall and adjacent walls.*
Source: *DeKay and Brown (2001)*

Similarly, convection will only draw cooler air from under the house or the lower parts of the home when the warmer air is vented through roof or ceiling vents or through windows and doors. However, convection will not function properly if the exterior areas near the windows and doors are radiating heat. This breaks up the temperature difference. Some of the methods for promoting convection include roof ventilators, grills, gable vents, louvers clerestory windows, exhaust fans, open eaves, vented ridges, solar driven ventilators and raked ceilings. Methods that create convection work even in calm or low wind conditions.

Poorly ventilated roof-spaces can get very hot and this heat is often transferred down through the ceiling into the room below. Ventilating the roof space will stop this. Floor and bottom wall grills permit cooler air from under and around the home to be brought into the home. The pool of cool air can be expanded by shading the external spaces around the house using planter beds and various landscaping ideas such as water features and vertical gardens on walls.

From the foregoing, it is generally agreed that, to achieve effective ventilation in hot humid climates at least two large operable windows should be provided on different walls, preferably one opposite the other, with one of them intercepting the prevailing wind. When the windows cannot be orientated to face the wind, wind deflectors, which may be in the form of appropriately placed in internal partitions, can be employed to channel air through the occupied zone (Tantasavasdi *et al,* 2001; Srisuwan, 2001). Obstruction of the air path should be minimized. Furthermore, indoors should be at the body level to increase potential for physiological cooling (Srisuwan, 2001). To facilitate the natural ventilation of rooms, the resistance to airflow through the building has to be minimized. This means having large openings for the passage of air, and reducing the number of rooms through which the air has to pass. A good example of this is a school classroom with verandah access and windows along opposite walls.

Research Methodology

Design of the study

The study adopted a descriptive survey research method.

Study Area

The study area is Uyo, the Capital City of Akwa Ibom State.

Population of the Study

The population of the study consisted of all middle income housing in Uyo Metropolis.

Sample and Sampling Technique

The respondents in the study consisted of 200 household heads that are selected randomly from all the households in Uyo metropolis, using simple random sampling method. The sample size was determined using sample fraction from Ibanga (1992)

Instrumentation

The following instruments were used to measure physical comfort variables, liquid crystal thermometers, Wet and dry bulb hygrometer, and anemometer for collecting data of the indoor thermal environment. **Also,** questionnaire and The CBE Thermal Comfort Tool (a computer model programme) (Tyler *et al.*, 2013) were used as tools to ascertain the prevalent comfort situation based on field measurements made.

Validity of Instrument

The instrument was face and contents validated by expert from test, measurement and evaluation.

Reliability of the Instrument

Crombach Alpha technique was used to determine the reliability of the questionnaire used in the study with a reliability coefficient of 0.84 to 0.94.

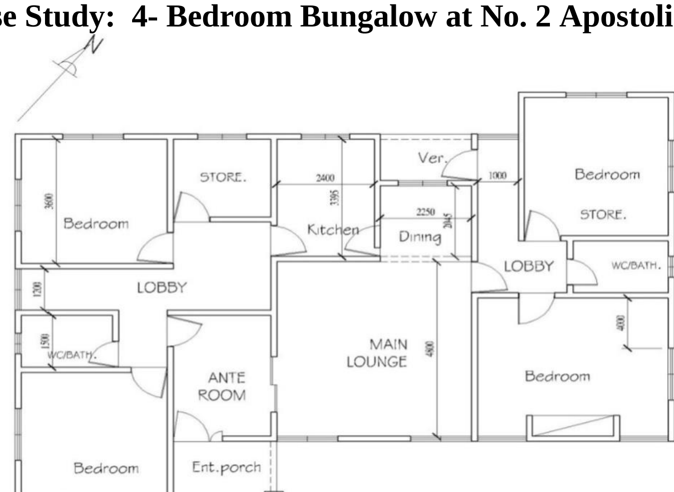
Sources of Data

The principal source of data used was from both the primary and secondary sources.

Methods of Analysis

Hypothesis was stated in the null form, and was tested using Pearson Product Moment Correlation analysis (PPMC) at significance level of 0.05.

Case Study: 4- Bedroom Bungalow at No. 2 Apostolic road, Idoro, Uyo.



GROUND FLOOR PLAN

Figure 3.9: *4- bedroom bungalow, No.2 Apostolic Road, Idoro. (Designed by Deeds House Consult, Uyo)*
Source: *Author's Field Work (2015)*

Plate V: *Front view of 4- Bedroom Detached Bungalow at Apostolic Road, Uyo.*
Source: *Author's Field Work (2015)*

Data Presentation and Analysis

Hypothesis Testing

The null hypothesis states that there is no significant relationship between architectural features of the building and the effectiveness of natural ventilation and thermal comfort. In order to test the hypothesis, two variables were identified as follows:

1. Architectural features of the building as the independent variable
2. Effectiveness of natural ventilation and thermal comfort as the dependent variable

Pearson Product Moment Correlation analysis was used to analyze the data (See Table 1).

Table 1: Pearson Product Moment Correlation Analysis Result of the relationship between architectural features of the building and the effectiveness of natural ventilation and thermal comfort

Variable	$\sum x$ / $\sum y$	$\sum x^2$ / $\sum y^2$	$\sum xy$	**R**
Architectural features of the building (XI)	1920	18560	18240	0.69*
Effectiveness of natural ventilation and thermal comfort (Y)	1880	18280		

***Significant at 0.05 level; df = 198; N = 200; Critical r-value = 0.139**
Source: Authors Field Work (2016)

Table 1 presents the obtained r-value of (0.69). This value was tested for significance by comparing it with the critical r-value (0.139) at 0.05 level with 198 degree of freedom. The obtained r-value (0.69) was greater than the critical r –value (0.139). Hence, the result was significant. The result therefore means that there is significant relationship between architectural features of the building and the effectiveness of natural ventilation and thermal comfort.

Discussion of Major Findings

There is significant relationship between architectural features of the building and the effectiveness of natural ventilation and thermal comfort. This is supported by the result of the data analysis in table 1 which is significant due to the fact that the obtained r-value (0.69) was greater than the critical r –value (0.139) at 0.05 level with 198 degree of freedom. The significance of the result caused the null hypotheses to be rejected while the alternative one was accepted. Uzuegbunam *et al* (2012) confirms this, when he stated that certain features, like roof aperture, when combined with cross ventilation system can help to maximize ventilation in buildings by stack effect. Several other investigations confirm this finding. Dekay and Brown (2001) states that wing-walls when properly placed by the wall aperture, especially where there is variable wind direction can improve the flow of indoor air in buildings. Autodesk Education Community (2015) states that properly hinged casement and jalousie windows can redirect prevailing winds to cross-ventilation. Srisuwan (2001), Tantasavasdi *et al* (2001) and Tantasavasdi (2002) conclude that to achieve effective ventilation, especially when the windows cannot be orientated to face the wind, wind deflectors, which may be in the form of appropriately placed internal partitions, can be employed to channel air through the occupied zone in buildings.

Conclusions

Based on the findings of the research work, the researcher deems it that many passive design strategies adopted by middle income housing owners in Uyo, Akwa Ibom State are not adequate enough for sustainable thermal comfort of the occupants. Quality of indoor thermal environments contributes immensely to the level of comfort satisfaction of occupants and this caused them to find it much conducive for continuous inhabitation in the house. Therefore, there is a significant relationship between architectural features of the building and the effectiveness of natural ventilation and thermal comfort.

Recommendations

1. The buildings should be orientated with their longer sides intercepting prevailing winds and the shorter sides facing the direction of the strongest solar radiation. This will help avoid heat stress in the building.

2. For the middle income earners and others to have the comfort of their buildings there should be an adoption of design that will improve upon the structure of their housing such as the prototype designed in this study.

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