EVALUATING VENTILATION EFFICIENCY OF WINDOWS IN SENATE BUILDINGS: A CASE OF NIGERIA UNIVERSITIES.

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Abstract: Natural ventilation occurs because of pressure difference acting on inlets and outlets of a space. This pressure difference can be created by wind or by a thermal chimney (Stack Ventilation). The study evaluated the ventilation efficiency of windows in senate buildings of selected Universities in South-West Nigeria. The study identified assessed ventilation efficiency of openings in the study area. Givoni Mathematical model was used to calculate the indoor air velocity and data obtained were analysed using descriptive statistics. Givoni empirical model indicated that none of the spaces investigated satisfied ventilation comfort standard of between 0.5-1.5 m/s for warm humid climate. The highest indoor air velocity occurred in University of Lagos where the casement window type was largely adopted with indoor air velocity of 0.41m/s and the lowest occurred in Ladoke Akintola University of Technology where the sliding windows were used with an indoor air velocity of 0.29m/s. The study concluded that with the use of casement window type, thermal comfort will be improved in office building.

Keywords: Air Velocity, Casement, Openings,Senate Buildings, South-West Nigeria, Thermal Comfort.

Introduction: Senate Building is categorized as an Administrative building and administration is connected with organizing the work of a business of an establishment. Thus, every establishment requires an administrative building to organize, run and conduct properly the overall affairs of their objectives to achieve the desirable set goal. Administrative building is a place where activities are carried out in order to plan, organize and run a business, school or other institutions. It is also a place where the progress and success of a business, school and other institutions are controlled and determined. (Fajobi, 2004). The administrative building houses the facilities that enhance the coordination of activities of the Academic Administration. Each University requires an administrative building (Senate Building) in order to achieve the goal for which the University is established, for this reason Senate building is the nerve centre of administrative and Academic Coordination of any University.

According to Olufowobi and Adenuga, (2006), a building is required to perform many functions and provision of thermal comfort is one of them. Energy consumed in buildings to provide thermal comfort is related to the climate in which the buildings are located as well as the thermal properties of the fabrics. In the course of providing thermal comfort for building occupants, it is essential to consider the influence of prevailing climatic conditions on the thermal performance of such buildings. This is particularly important in the design of low-energy consuming buildings. Funds for the construction and operation of public buildings are generally not sufficient as to stretch it to provide air-conditioning facility in these buildings. Such public or non-prestigious buildings include schools, hospitals, and government offices in rural areas. Despite the paucity of funds, it goes without saying that, the thermal comfort of the users of these buildings is essential to their health and performance at work. Particularly for residential buildings, thermal comfort and mental ability are important and are related to each other.

It is known that ventilation has the following three major functions:
(i.) Replacement of stale air with fresh air from outside to promote good health
(ii.) Cooling of indoor air and cooling of building structures
(iii.) Body cooling for comfort.

Thus (ii) and (iii) above are related to the use of natural ventilation to provide relief from thermal discomfort. The supply of fresh air for good health is required in all buildings throughout the world. Whereas, health ventilation is all that may be required in buildings located in temperate and cold climates, this is not so in low-energy buildings in warm climates, where the need goes beyond fresh air supply; there is additional requirement for natural ventilation to offer relief from warm discomfort by way of physiological cooling.

Natural ventilation is created by pressure differences between the outside and the inside of the building; this pressure difference may be wind-driven, or due to air temperature differences (buoyancy effect). In general, wind-driven natural ventilation is easier to achieve in a warm-humid climate as that of Nigeria; it merely requires a low outdoor wind speed to create adequate indoor air speeds. The air temperature differences are usually not high enough to generate any effective air movement. In a study by Shodeinde in 1990 on thermal conditions in some naturally ventilated residential buildings in Lagos, Ajani (2015) stated that the temperature differences between the outside air and inside air were not more than 1.5°C. In another study of natural ventilation for houses in Thailand, Tantasavasdi et al (2001) found that buoyancy effect can create indoor air speeds only as high as 0.1m/sec. On the other hand, the study found that wind-driven effect could easily create higher indoor air speeds up to 0.4m/sec (Olufowobib, 2012). However, there has not been much research work on ventilation efficiency of windows in this warm humid climatic region like Nigeria. With this view, the study aims at evaluating the ventilation efficiency of windows in senate buildings in South – West Nigeria Universities. Therefore in addressing the thermal comfort (Indoor Air Velocity) in the offices of the study area to support the research the following research questions addresses the window conditions:

1. What are the types of windows in use in Senate Buildings of south west Nigeria University?
2. What are the sizes (area) of windows in use in the study Area?
3. What are the sizes (Floor Area) of offices in the Senate Buildings in the Study Area?

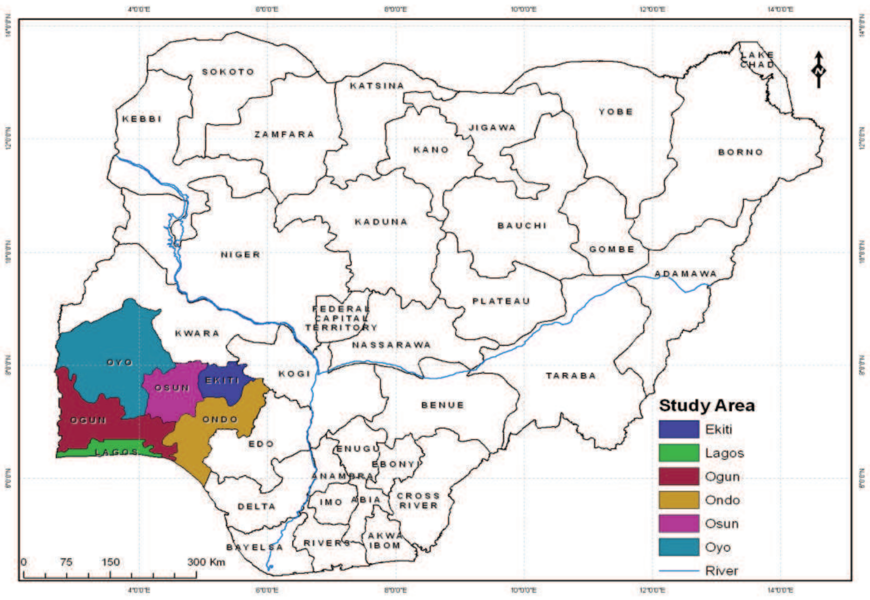
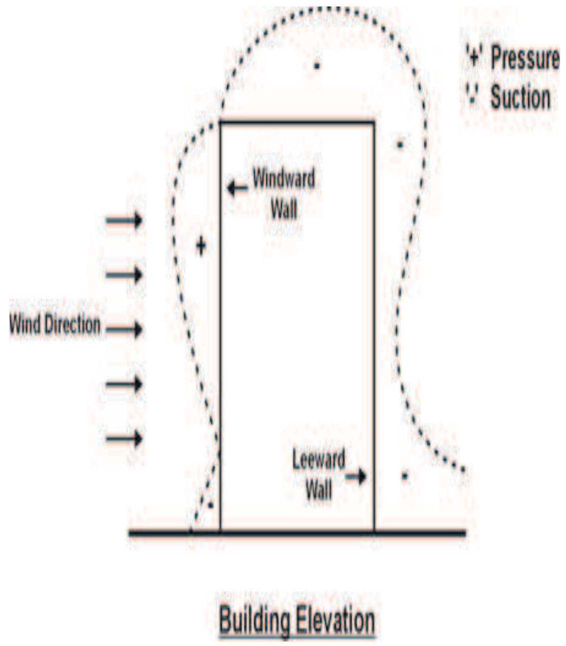


Figure 1: Map of Nigeria, showing South-West Nigeria

Literature Review: Natural ventilation occurs because of pressure differences acting on inlets and outlets of a space. This pressure difference can be created by wind (Figure 2) or by a thermal chimney (stack ventilation)(Figure 3). The pressure difference caused by winds may be steady (as in cross ventilation) or unsteady (as in turbulent ventilation). Steady wind-driven ventilation, i.e., cross ventilation, is usually the strongest mechanism and is produced when a prevailing wind direction creates distinct positive and negative (suction) pressures at the inlets and outlets of a volume. Unsteady pressure differences also may be created by wind, such as changing pressure patterns over a windward wall with two widely spaced windows on the same wall. (Zahra, 2010) The fluctuating wind directions, typical in suburban or other rough terrain, create unsteady pressure fluctuations that can generate significant ventilation. Another type of natural ventilation arises in rooms with only one window. Here minimal ventilation is created as some air enters the room at one time and a few seconds later some air exits because of the fluctuating static pressure of the wind. This pattern creates very minimal ventilation and will not be discussed further. The theoretical analysis of this type of "turbulent diffusion" ventilation is explained by Warren and Parkins (1984). Historically, the available airspeeds in ventilated rooms with different room geometry and window configuration have interested natural ventilation researchers. Studies were usually done by testing scale model buildings in wind tunnels. In the early 1950s, a comprehensive series of wind tunnel tests were conducted at the Texas A&M University using a uniform speed wind tunnel. A summary of those investigations is provided by Evans (1979). A detailed summary of the research results useful to the building designers is given by Reed (1953). Many of the airspeed patterns in rooms observed by the Texas A&M group have been summarised in pattern diagrams by Bowen (1981).



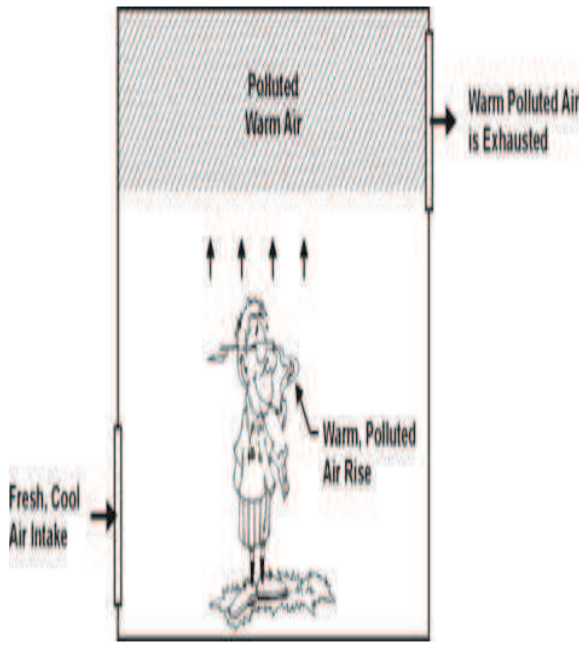


Figure 2: Wind Driven Ventilation **Figure 3: Stack Ventilation**

(**Source:** Etheridge & Sandberg, 1996; Awbi, 2003)

Windows Ventilation: The changes in airflow patterns caused by different types of windows were investigated by Holleman at Texas A&M (1951). as shown in Figure 1 Holleman found that fully open projection windows were capable of directing air at occupant level because of the slots. Such slots were also responsible for the good performance of casement windows for oblique wind incidences.

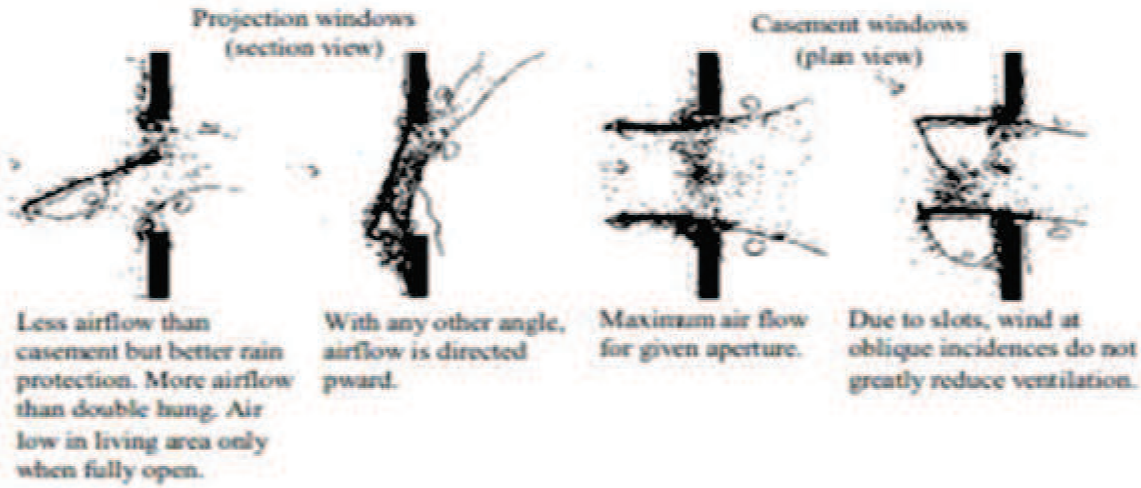


Figure 4: Air Flow Pattern
Source: World Academy of Science, Engineering and Technology International Journal of Architectural and Environmental Engineering Vol:4, No:11, 2010

Window Types Used In The Study Area:

Casement Window Type

Projected Window Type

Louvered Window Type

In the 1960s Givoni conducted another thorough set of wind tunnel studies using a uniform wind tunnel. Many of the findings can be found in Givoni (1976). But many more interesting findings regarding airspeeds in building groups and buildings with courtyards, methods to cross ventilate double-loaded corridors, and building layout for apartment buildings to enhance ventilation are only cited in the original research report by Givoni (1968). Givoni demonstrated the usefulness of adjacent windows. He found that rooms with windows on adjacent walls ventilated better than traditional cross-ventilated rooms with windows on opposite walls when the incident wind angle was perpendicular to the inlet. At oblique wind incidences (45° incidence angle to inlet) traditional cross-ventilated rooms performed better than rooms with adjacent windows. The estimation of room air change rates, average room surface temperatures and room air temperatures enables one to predict the cooling or heat removal rate for natural ventilation. However, it is very important to note that the room air change rate may not be related to air flow rates through the openings. Consider normal wind incidence and windward and leeward openings directly in line with one another. Depending on the ratio of the areas of opening, the air can rush through without significantly mixing and entraining room air. As a result, little heat will be removed and circulation in many parts of the room will be poor. Staggered windward and leeward openings that force the air to turn are better for ventilation. For similar reasons, winds at an oblique rather than normal incidence provide better cooling if the apertures are not staggered (1980). In the 1960s Sobin conducted another comprehensive wind tunnel study at the Architectural Association (London). Sobin was the first to use a boundary layer wind tunnel for natural ventilation studies. A boundary layer wind tunnel differs from the uniform speed wind tunnel used in aeronautical studies in that the former simulates both the variation of wind speed with height and the natural turbulence of the wind. Sobin published some of his findings in 1981. Sobin investigated many interesting window types and measured room airspeeds both in section and plan. One of his most interesting findings relates to window shape. He found horizontal windows (windows that are wider than their height) created greater wind speeds than vertical windows (windows that are higher than their width). This effect was more pronounced for oblique wind incidences. It is interesting to note that Givoni's apertures were also horizontal and he also found good performance at oblique wind incidences. Aynsley et al. (1977) continued airspeed measurements in a building with wind scoops. Insect screening is a necessary consideration in ventilation in many parts of the world. Givoni [1976] found that screening entire balconies produced greater airspeeds in rooms than did screening the windows. Van Straaten [1967] measured the decrease in airflow caused by screens and found that it was dependent on the incident wind speed. For a 1.5 mph (0.7 m/s) wind, the airflow was reduced by 60%, whereas in a 6 mph (2.7 m/s) wind the reduction was only 28%. This difference is possibly due to the reduction of the wake region behind a cylinder as the Reynolds number increases. Internal airspeeds can only be predicted by solving the three-dimensional turbulent flow equations, a difficult task that has been attempted by only a few [1974], [1984]. White of Texas A&M [1954] investigated airflow reductions caused by landscaping elements such as trees and hedges. He also discovered using solid paper and landscape moss models of trees and hedges, that certain landscaping schemes are advantageous for increasing ventilation in building [1979].

Effect of Window Design on Natural Ventilation:
The effect of various window configurations and architectural factors on indoor air movement, including wind orientation, cross-ventilation, inlet/outlet area ratio, inlet shape, window location and window accessories, was reported in an experimental wind tunnel study by Sobin [1980].

A. Orientation The effect of orientation to wind or wind angle on ventilative cooling was found to vary with the physical characteristics of the window configuration used, and in particular the characteristics of window location, shape, size and accessories. Generally speaking, for the majority of window configurations tested, orientation of inlets at 90° to the wind provided the highest average indoor speed ratios, with airflow velocities dropping off rapidly with external wind shifts to either side of 90°. Significantly enough, however, it was found that certain combinations of inlet characteristics (especially shape), while providing substantially similar results with 90° wind are also capable of providing equal or better ventilative cooling in oblique (up to 45°) winds than they do in normal (90°) winds. This is a finding of particular importance since wind direction is of course rarely if ever constant. If window systems are to take maximum advantage of wind-powered ventilation, they should be selected where possible to provide a reasonably "broad band", not a strongly "peaked" directional response providing greater effectiveness under customary conditions in which the wind changes direction over a certain range of directions on an hourly, daily, or seasonal basis. This is the case even in areas of great directional constancy, such as trade wind locations, where, as on the coastal regions of Caribbean islands, directional shifts of up to 90° take place during each 24-hour period. These directional effects are described with respect to each of the window design characteristics discussed below.

B. Cross-Ventilation Test results confirm that for optimum ventilative cooling, sufficient effective area of inlet and outlet openings is required, with the inlet/s located in a zone of positive pressure and the outlet/s in a zone of negative pressure. Rooms equipped with inlets only tend to provide very much reduced indoor speed ratios (though demonstrating somewhat improved performance in oblique winds), especially in the case of horizontally-shaped openings. The configuration with inlets only corresponds to the frequently encountered arrangement in which rooms are provided with windows on one side of a building only. The relative improvement produced by oblique wind can amount to as much as 250%, where the single opening is located on a windward facade, but the overall result even under these conditions at best amounts to only one third of the average speed ratios provided by a cross-ventilating configuration. Smoke-tracing investigations of "one-sided" configurations show that in oblique and normal winds, single opening functions as both inlet and outlet. Motive power for indoor airflow thus originates in pressure differences across the opening (almost always small in 90° wind, but somewhat more substantial in oblique wind).

C. Inlet Outlet Area Ratio Test results confirmed that where inlet and outlet opening are equal, as their areas increase, increases occur in the amount of indoor ventilative cooling they produce. Since, however, window sizes are not determined by ventilation alone but must also take into account other architectural factors such as day lighting, privacy, security, and solar control, a significant question for ventilation purposes is how best to distribute a given and usually limited amount of opening area. An important parameter here is the relative distribution of area as between the inlet/s and outlet/s. Sobin's preliminary test results suggest that for a given total opening area, the highest euphoric indoor speed ratios throughout rooms are achieved when the ratio Ao/Ai is approximately l.25, that is, when the inlet is slightly smaller than the outlet. Inlets substantially smaller than outlets produce high local velocities in the vicinity of the inlet itself, but lower speed ratios when results are averaged across the entire room. It thus appears advisable to provide approximately equal inlets and outlets, or a very slightly smaller inlet, where maximum ventilative cooling is required.

D. Inlet Shape A review of test results suggests that inlet shape is the single most important window design parameter in determining the efficacy of wind driven ventilative cooling. Square and vertical inlet openings produce a sharply peaked or "narrow-range" response under conditions of changing wind direction, with both types attaining maximum performance in a perpendicular (90°) wind, but falling off rapidly in efficiency with even small departures of wind direction from the perpendicular. At 45° , for example, vertical inlet performance has decreased by more than 17%, that of square inlets by more than 26%. On the other hand, horizontal inlets not only have a substantially higher average performance for all wind angles, but in contrast to square and vertical inlets, horizontal inlets actually improve their effectiveness in angled winds, producing two maxima at wind angles in the vicinity of 45° to either side of the perpendicular, while showing a relatively flat, or "wide-range" response throughout this 90° quadrant of wind angles (or orientations). The improvement of horizontal inlets in oblique compared to perpendicular wind angles can amount to 30% or better and depends on the relative opening sizes used. For example, given equal areas of inlet and outlet, where each opening is equal to 22% of the inlet and outlet wall areas respectively, the increase in average indoor speed ratio for horizontal inlets in a 45° wind compared to a 90° wind is typically in the order of 16%. Horizontal inlets were found to increase their performance in oblique winds in fully cross-ventilated rooms (openings in opposite walls), in diagonally-ventilated rooms (openings in adjacent walls), and in rooms with inlet openings only. From the results of Givoni's ventilation study [1962], he reached the general conclusion that better ventilation is often achieved when the wind is oblique to the inlet. With respect to this conclusion, however, it should be noted that all inlet and outlet openings tested by Givoni were horizontally shaped; no "square" or "vertical" opening shapes were included in his tests. Another of Givoni's conclusions not supported by the results of the present study concerns his explanation for the superiority of oblique wind angles. Givoni suggests that when airflow has to change direction inside a room, as it must with wind oblique to the ventilation-axis (defined as a line drawn between the centre points of the inlet and outlet openings), a larger proportion of room volume becomes involved in the flow resulting in higher average velocities. Test results from the Sobin's study [1980] indicate, however, that a change in direction of airflow inside a room does not necessarily lead to increased air movement; on the contrary it is often substantially reduced. Smoke-tracing shows, for example, that in oblique winds, strong directional changes take place inside rooms equipped with square or vertical inlets, yet these two inlet types consistently provide substantially lower average indoor speed ratios in oblique than in perpendicular wind, typically showing relative losses of 25% or more in a 45° wind. A more comprehensive hypothesis, capable of explaining the full range of observed changes in performance with different opening shapes appears to require inclusion of at least two factors in addition to flow patterns:

(1) the influence of wind angle on the effective inlet area, and

(2)external wind-pressure distributions. It should also be observed that horizontally-shaped inlets tend to produce a broader, flatter, more "room-wide" jet or sheet indoor airflow than do vertical or square ("hole-in-a-wall") shaped inlets. This fact may help to explain, at least in part, their clearly superior ability to provide higher average amounts of ventilative cooling throughout the interior of rooms.

E. Window Location Preliminary results suggest that in general, ventilative cooling performance is improved when the inlet and outlet are arranged so that the ventilation axis is parallel to the wind. This condition occurs either

(a) when the inlet and outlet are located directly in line with one another on opposite walls of a room, with the wind perpendicular to the inlet; or

(b) when the inlet and outlet are located in adjacent walls of a room, and an oblique wind passes successively through the inlet, through at least one corner of the room, then passes through the outlet. It should be noted that in both of these cases, the main tube or jet of airflow passes directly from inlet to outlet without changing direction inside the room. The only previous study to have examined the diagonally-ventilated room configuration [1962] and which reported a test result contrary to that attained in the present study, proceeded to use this result as a basis for concluding that ventilation is improved wherever airflow changes direction inside a room. The Texas [1954] studies found that while airflow was maximised by equal inlet and outlet areas, airspeeds in rooms were locally maximised (particularly near the inlet) if the outlet was slightly larger than the inlet. They found that while the outlet location did not affect the airflow pattern significantly, the inlet location controlled the airflow pattern. A high inlet directed airflow near the ceiling, whereas a low-to-medium height inlet directed airflow to the occupant levels. However, even a mid ceiling height level inlet at the second floor directed air to the ceiling. They also observed the "wall jet" effect. If the inlet is near a corner, the air tends to lair along the nearest wall.

F. Window Accessories Window accessories have been traditionally designed to work as sun shading, privacy or security devices, not as airflow controls. However, window "equipment" designed to produce solar or rain protection, visual privacy. Shielding and other non-aerodynamically related purposes can frequently have unintentioned, yet at times seriously deleterious effects on wind-powered ventilative cooling. Earlier studies have recognized this problem; the present results confirm its importance. One instance of the unfavorable effect of window equipment revealed by present test results is the aerodynamic effect of fixed or movable horizontal and vertical louvres. The effect of primarily horizontal louvres or canopies on indoor airflow speeds and patterns is chiefly manifested in section. Horizontal louvres have the tendency, when adjusted to typical angles, to direct airflow toward the ceiling, thus greatly reducing ventilative cooling effectiveness within the room's occupied zone. However, the effect of primarily vertical louvres chiefly shows up on plan. For example, horizontal louvres used on vertical inlets do nothing to alter the basically peaked, "narrow-band" and symmetrical plan-response of this type of opening to changing wind angles, regardless of the blade setting angle. The same phenomenon is created by inlet accessories which incorporate vertical elements, which also tend to produce a strongly peaked. Narrow-band directional response, provides maximum average indoor airflow when the vertical elements present the minimum degree of airflow resistance, i.e., when they are parallel to the wind. For example, when vertical louvres are set perpendicular to the plane of an inlet opening, they tend to cut off diagonal wind; yet when oriented at an oblique angle they sharply favour diagonal winds arriving at angles close to that same direction. By the addition to vertical control elements, it is also possible to "convert" the typical "broad-band" directional response of horizontal inlets, into the "narrow-band" response of square or vertical inlets. In general, as the wind angle shifts, vertical "window furniture" produces an effective change in inlet area. The degree of change depends on the angular relationship between the accessory elements and wind direction. Increasing the angle increases "narrowing", and decreasing the angle increases effective inlet area where it is not possible or desirable to orient opening accessories to face the wind, flow-directing accessories such as louvres can be placed within or across the inlet opening to "turn" wind to enter belladonna. But results show that considerable resistance losses of up to 50% or more are incurred by the use of such techniques, suggesting that wherever possible flow-directing accessories should be located adjacent to inlets, not within them.

Research Methodology: Givoni, (1976) Mathematical model was used to calculate the indoor air velocity of the spaces investigated. The data required are window characteristics and the wall area as well as the floor area. The data collected are both primary and secondary. The primary data is informed of physical observation to get the floor area and the window area. The Secondary data is in form of chart, gotten for journals to get the indoor air velocity. Givoni (1976) Mathematical Model was used to compute the corresponding indoor velocity of the spaces under consideration; window sizes as well as the area of both the floor and the wall were considered.

There are several Offices in the selected Senate buildings. This represents the sampling frame. The study purposefully selected typical offices, Registrar Office and Vice-Chancellors office. The typical office was selected because it constitutes the largest number in the selected senate building. The Registrar office and Vice-Chancellor's office was selected because they have another type of orientation unlike other offices; in terms of location of windows, number of windows, sizes of windows, floor area and wall area.

Definition of Variables:

1. Typical Office – Typ. Off.
2. Registrar's Office- Reg. Off.
3. Vice- Chancellor's Office- V.C's Off.
4. Sectary to Vice- Chancellor's Office - Sec. to V.C's Off.

Objective: To analyze Ventilation Efficiency of Openings in the Study Area

Guvoni (1976) Mathematical Model:

$\mathbf{V_i = 0.45\ (1- exp^{-384x})\ V_o}$

Where V_i = Average Indoor velocity (Table 3.4).

X = The ratio of window area to wall area

V_o = The Outdoor wind Velocity.

Where V_o = 1.2m/s (Average of Five years data (2005-2009) of outdoor wind velocity of Abeokuta). Gotten from the table 1.

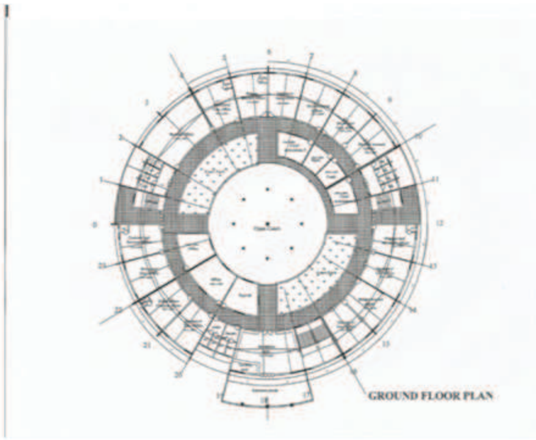
Note: For ventilation comfort in Warm Humid Climate Indoor air velocity should be within the range of 0.5 – 1.5 m/s (Ayinla, 2011)

Observed Senate Buildings:

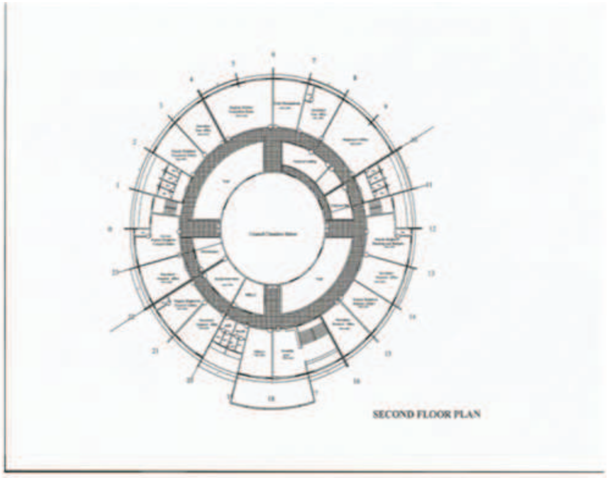
Picture showing the UNILAG Senate Building
Source: Author's Field Survey, 2017

Approach Elevation of the OAU Senate Building.
Source: Author's Field Survey, 2017

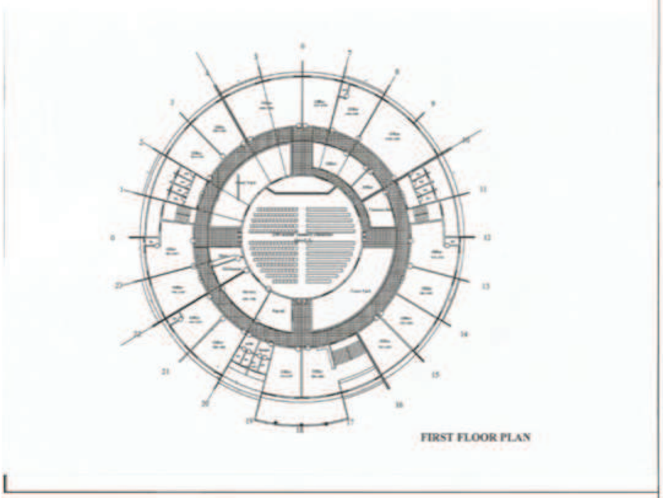
Approach view of LAUTECH Senate Building
Source: Author's Field Survey, 2017



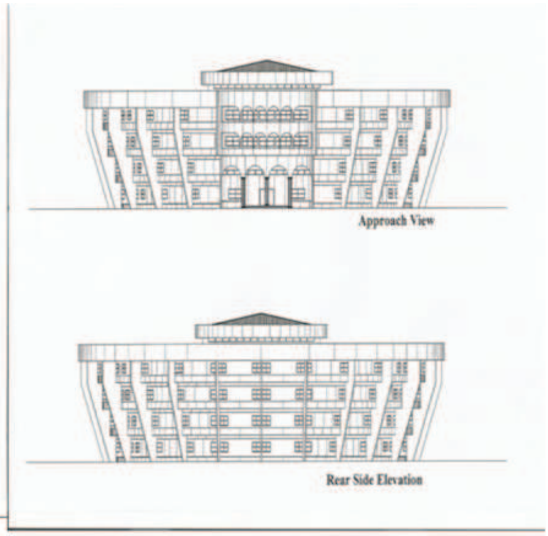
Showing the Ground floorplan of LAUTECH Senate Building
Source: Author's Field Survey, 2017



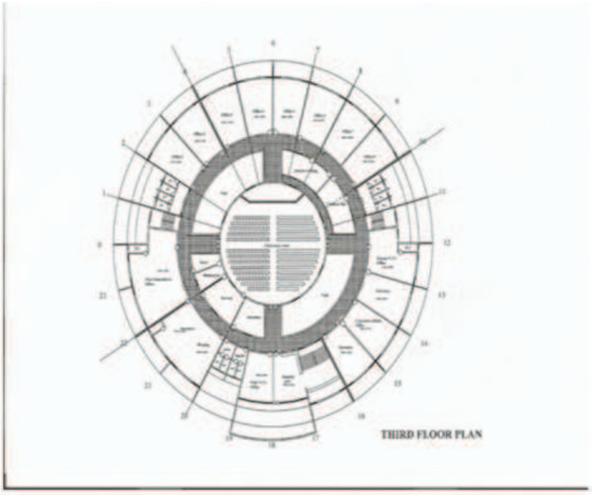
First Floor Plan of LAUTECH Senate Building
Source: Author's Field Survey, 2017



Second Floor Plan of LAUTECH Senate Building
Source: Author's Field Survey, 2017



Approach and Rear Elevation of LAUTECH Senate Building
Source: Author's Field Survey, 2017



Third Floor Plan of LAUTECH Senate Building
Source: Author's Field Survey, 2017

Right and Left side Elevation of LAUTECH Senate Building
Source: Author's Field Survey, 2017

Table 1: Types of Window Used

	Windows types											
	Louvre Window			Projected Window			Sliding Window			Casement		
Selected Senate Building	Typ. Off.	Reg. Off.	V.C's Off.	Typ. Off.	Reg. Off.	V.C's Off.	Typ. Off.	Reg. Off.	V.C's Off.	Typ. Off.	Reg. Off.	V.C's Off.
OAU				96	2	2						
LAUTECH							101	2	2			
UI				23	2	2				36	2	2
UNILAG	35	2	2							96	2	2
TOTAL	35	2	2	119	4	4	101	2		132	4	4
GROUND TOTAL	39 (9.5%)			127 (30.0%)			105 (25.5%)			140 (34.0%)		

Source: Author's Fieldwork, April 2017

Table 1 reveals the distribution of window types in the study area. Most of the windows in the study area are projected window. The table revealed that One hundred and Forty (34.0%) of the windows were casement type, One hundred and twenty seven (30.0 %) were projected, one hundred and five (25.5%) were sliding; while thirty nine (9.5%) were louvered type. Each university has their peculiar usage of window type. The result shows that when proposing for window type, projected and casement should be considered in constructing senate building. Thus, the result analysis shows that casement is highly acceptable because of it is open to strong blast of wind (Table 1). However, this result supported the outcome of the research done by Iannone and Adebamowo in 1999 and 2004 respectively.

Average Indoor air velocity of the Vice-Chancellor's Office, Registrar's Office, Secretary to V.C's Office and a typical Office are shown in table 3. Givoni method described in table 3 was used to compute the indoor air velocity in the spaces. The recommendation of Borda-Dias (1989) that the average indoor wind speed in warm humid climate should be between 0.5-1.5m/s, the recommendation was adopted not only because it was the lowest value available but also other scholar like Arens (1984), Ajibola (1997), Adunola (2006) and Ayinla (2011) have adopted it in the past. The result from table 3 indicated that none of the spaces investigated satisfied ventilation comfort standard of between 0.5-1.5 m/s for warm humid climate. The highest indoor air velocity occurred in University of Lagos where the casement window type was largely adopted with indoor air velocity of 0.41m/s and the lowest occurred in Ladoke Akintola University of Technology where the sliding windows were used with an indoor air velocity of 0.29m/s.

Table 2: Wind Power Simulation Using Available Wind Speeds in Abeokuta for 2002-2009

Year	Mean wind Speed M/s	Standard deviation σ(m/s)	Shape parameter K	Scale parameter C(m/s)	Air density ρ(kg/m)	Probability distribution function F(V′)	Cumulative distribution function M(V′)	Power Coefficient C	Power density p (W/m^2)
2002	1.525	1.799	0.835	1.3822	14.243	0.2007	0.6623	0.593	14.977
2003	0.4828	0.4359	1.117	0.1966	13.698	0.4125	0.9347	0.593	6.457
2004	1.444	0.92	0.452	0.1912	13.506	0.3448	0.7686	0.593	13.351
2005	1.636	0.1129	1.84	1.6293	12.901	4.1254	0.6599	0.593	16.749
2006	1.078	0.043	1.913	0.0879	12.901	8.8064	0.5487	0.593	4.018
2007	1.068	0.073	0.925	0.0655	12.552	5.0012	0.6449	0.593	4.117
2008	1.053	0.03	1.859	0.0596	12.707	12.6207	0.5525	0.593	5.020
2009	1.148	0.141	1.054	0.1511	12.683	2.6193	0.6241	0.593	4.012

Source: Adejumobi & al. - Hybrid Solar and wind Power

Table 3: Indoor Air Velocity in Spaces

Indoor Air Velocity in Spaces																
	Reference Window Area (m^2)				Reference Wall Area (m^2)				Window / Wall Area Ratio (x)				Average Indoor Air Velocity (v) (m/s)			
SELECTED SENATE BUILDING	V.C's Off.	Reg. Off.	Sec. to V.C's Off.	Typ. Off.	V.C's Off.	Reg. Off.	Sec. to V.C's Off.	Typ. Off.	V.C's Off.	Reg. Off.	Sec. to V.C's Off.	Typ. Off.	V.C's Off.	Reg. Off.	Sec. to V.C's Off.	Typ. Off.
UNILAG	3.6	3.6	3.6	3.6	22.8	21.5	19.8	10.80	0.15	0.16	0.18	0.33	0.46	0.40	0.40	0.40
UI	3.6	3.6	2.7	3.6	18.2	15.84	15.84	15.84	0.19	0.22	0.17	0.22	0.42	0.39	0.39	0.39
OAU	2.7	2.7	2.88	2.7	17.8	15.6	15.6	15.6	0.15	0.17	0.18	0.17	0.45	0.36	0.36	0.36
LAUTECH	2.88	2.88	6.48	2.88	25.0	19.8	19.8	19.8	0.11	0.14	0.32	0.14	0.31	0.29	0.29	0.29

Source: Author's Fieldwork, April 2017

Conclusion: Physical observation of the window types and location in the selected Senate buildings revealed that 140 (34.0%) of the windows were casement type; 127 (30.0 %) were Projected; 105 (25.5%) were sliding; while 39 (9.5%) were louvered type. The study further showed that the highest indoor air velocity occurred in University of Lagos where the casement window type was largely adopted with indoor air velocity of 0.41m/s and the lowest occurred in Ladoke Akintola University of Technology where the sliding windows were used with an indoor air velocity of 0.29m/s. However, this research has gone ahead in solving more than the persisting problem of ventilation and space in the Senate building. Circulation and orientation of building for the avoidance of glare and many more were also solved.

Recommendations: The study hereby recommends that with adequate sizes, casement window type is the best for office building design and for thermal comfort. This study also informs the policies makers about orientation and shape of the office buildings to enhance the natural ventilation.

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