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Assessment of Passive Architectural Strategies for Natural Ventilation in Libraries within Hot- Humid Climate

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ABSTRACT

In buildings, natural ventilation is for human comfort; for odour removal, body and the structure cooling. A previous study revealed that libraries in Nigeria could not function efficiently without artificial ventilation and lighting. Artificial ventilation, aside from economic disadvantages, it is not reliable and anti-sustainability while natural ventilation is reliable, consume less energy, and in other words, it is more efficient when compared with other types of ventilation. The research evaluates the application of passive architectural strategies for natural ventilation in libraries within the hot-humid climate of Nigeria, intending to recommend natural ventilation strategies in libraries. Ten (10) libraries were selected randomly in the study area from both institutional and public libraries. The research conducted using observation schedule, the variables in the research are; Window types, Clerestory windows availability, Door openings, Screen walls, Courtyard, Other openings, use of external shading devices and orientation of the library. The data analysed using descriptive statistic; the results presented using tables, bar charts and pie charts. The research revealed that 29% of the cases studied use external vertical structural shading devices, 36% use horizontal shading devices, 21% use both vertical and horizontal shading devices to deflect solar radiation and 14% do not use any external shading devices. 80% of the libraries studied was oriented toward north-south (NS) direction, while 20% oriented toward east-west (EW) direction. Therefore, the majority of the libraries studied have desired orientation; however, each lacks one of the passive cooling strategies. Adequate natural ventilation in the libraries is achievable by the proper synthesis of the building orientation, proper design of building internal spaces, the proper position of window openings and use of projected window as well as clearstory. More so, further study to enhance natural ventilation configuration for the study area is desirable.

Keywords : Natural ventilation, Libraries, Window, Orientation and Nigeria.

I. INTRODUCTION

Ventilation deriving from the Latin “Venus”, meaning, the movement of air, it is defined as air changes in buildings (Crosbie & Callender, 1997). Natural ventilation is the process of supply and the removal of

air through an indoor space by passive means, that is, ventilation achieved without mechanical system, but by wind pressure and stack effect (Ogunsote, 1993; Sealey, 1979). Natural ventilation in the building is for human comfort. Also, defined as the use of wind and temperature differences to create airflow in and

through the buildings (Larsen & Heiselberg, 2008). Natural ventilation so preferred by building occupants, especially if they have some control over it, that is, with operable windows (Bakay, Bergmann, Bodas, Papp, & Szabo, 1988).

Proper natural ventilation is an essential factor in every library, both public and institutional. It is necessary for the desired learning to take place in the library. Therefore, ideal placement and position of windows openings for proper natural ventilation in the building (libraries) are necessary a design criterion (Ikechukwu, Lin, Idowu, & Okonkwo, 2019). therefore, it essential to keep an eye on the air quality of inside the library where the library users spend most of their time searching for information. This effort would facilitate the users understanding of their studies or research (Edwards, 2009; Oyedum & Nwalo, 2011).

Natural ventilation has been into use throughout history as a means to ventilate and passively cool structures. With the advent of more densely populated buildings, with more computers, higher internal heat loads, and more in-depth floor plans, buildings have moved toward tighter construction, controlling the air introduced into the building, are generally cooled mechanically. It is the increased heat load and concerns over occupant comfort that often restrict dependence on natural ventilation in library buildings.

The attainment of uniform internal temperatures for occupant comfort believed to be possible only by controlling the amount of air been supplied to an occupied space and its temperature (Drake, de Dear, Alessi, & Deuble, 2010; Negreiros, Pedrini, & Edwards, 2016). Currently, the Sustainable Building and Construction Initiative, a global partnership between the United Nations Environment Programme (UNEP) and global companies worldwide, is aimed at promoting a worldwide adoption of sustainable buildings and construction practices. According to

(Seppänen & Fisk, 2002), almost 40 per cent of CO₂ emissions in Europe, and 35 per cent in the US, are caused by buildings in operation: heating, air-conditioning systems, and energy consumption and probably in Nigeria.

A study revealed that most library buildings in Nigeria could not function efficiently without an artificial source of ventilation and lighting (Ayoosu, 2018). This source of ventilation, besides its economic disadvantages, is also not reliable and has sustainability problems. However, natural ventilation is more efficient, reliable and consume less energy when compare with other sources of ventilation. In Nigeria, the epileptic power supply is on top gear; these imply that buildings need natural lighting and ventilation (Ayoosu, 2016). The Vitruvian principles of firmitas, utilitas, and venustas are fundamental in any architectural design; thus, buildings are required to be durable, useful, and beautiful (Hrehovcsik & van Roessel, 2013). Ventilation requirement in the interior of the library building is to make the structure useful as a space for patrons, and it is critical. In tropics, ventilation is encouraged with the use of configuration that aids of adequate natural ventilation (Leng, Ahmad, Ossen, & Hamid, 2015).

Therefore, this research aims to evaluate the application of natural ventilation architectural strategies in libraries within the hot- humid climate of Nigeria to recommend natural ventilation design strategy for libraries.

II. PRINCIPLE OF NATURAL VENTILATION

The shape of a building, together with ventilation openings determines how natural ventilation operates (Allard & Allard, 1998). The four different principles of natural ventilation include; single-side ventilation, cross-flow ventilation, stalk ventilation and top-down ventilation (Ohba & Lun, 2010) as presented in figure 1. The principle of natural ventilation indicates how the exterior and interior airflows are linked, and

hence how the natural driving forces utilised to ventilate a building. Also, the principle of ventilation indicates how the air introduced into the building and how it is exhausted out of it. The libraries in the study area mostly utilised the cross-flow ventilation.

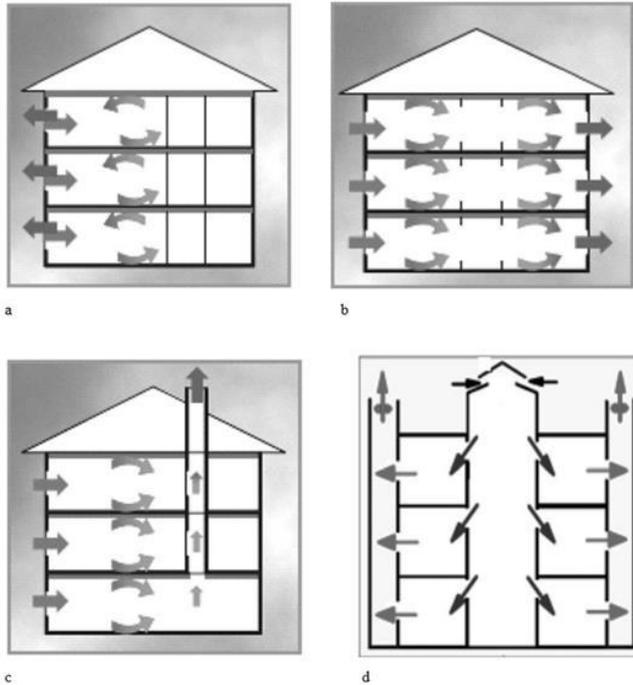


Figure 1 : Ventilation principle: (a) single-sided ventilation; (b) cross- flow ventilation; (c) stalk ventilation; (d) top down ventilation

III. METHODS AND MATERIAL

A. Study Area

The Hot- humid climatic region of Nigeria is in the tropics and has an average air temperature of 18o- 24o min, and 29o- 32o max. The average humidity ranges between 55-100% while the wind characterised by low velocity and a calm frequency (Koenigsberger & Ingersoll, 1974). It has two seasons namely, wet/rainy season (March/April – September/October) characterised by rains accompanied with a south-westerly wind and the dry/harmattan season (October/ November- February /March) which is characterised by dry cold air with occasional dust brought in by the north-east trade wind. The trade winds speed is averagely between 6-7 m/s. It has an average annual rainfall range of 500-

1300mm in May/June to September and green vegetation cover (Ogunsote & Prucnal-Ogunsote, 2002).

B. Research Methodology

Proper investigations of the study areas conducted to familiarise with the study areas. These, however, allows the researchers to relate all concerned with the aim of the research. Primary data were collected directly from case studies using an observation schedule entirely. Sketches of the library plans as well as photos were collected. Secondary Data were from library materials, such as textbooks, journals, magazines and internet sources.

The passive strategies of ventilation identified in the ten selected libraries are the various openings in the libraries that are in one way or the other aided natural ventilation. These include Window types, Clerestory windows, Door openings, Screen walls, Courtyard, and Other openings. It also includes the use of external shading device type and the building orientation

The population of the research comprises ten randomly selected public and institutional libraries in hot-humid climate zone of Nigeria. The libraries selected include Abubakar Gimba Library IBB University Lapai, Federal Polytechnic Bida Library, Federal University Lokoja Library Lokoja, National Library Minna, Nnamdi Azikiwe Library University Of Nigeria Nsukka, Federal University of Technology Minna Bosso Campus Library, IBB Library Federal University of Technology Minna Gidan Kwano Campus, Francis Idachaba Library, University Of Agriculture Makurdi, Hezekiah Oluwasanmi Library Obafemi Awolowo University Ile-Ife, and Kogi State Polytechnic Lokoja Library.

Descriptive statistics, using cross-tabulation and frequency and percentages analysed using Microsoft excel 2016 and results presented on tables, pie charts, and bar charts.

IV. RESULTS AND DISCUSSION

A. Identification of Window Types

TABLE I
TYPE OF WINDOWS USED IN THE STUDIED LIBRARIES

Names of Library	Reading Areas	Reference section	Serial section	E-library	Percentage
Abubakar Gimba Library, IBB University Lapai	Sliding	Sliding	Sliding	Sliding	100% Sliding
Federal Polytechnic Bida Library	Projected	Projected	Projected	Projected	100% projected
Federal University Lokoja Library Lokoja	Casement	Casement	Casement	Casement	100% casement
National Library Minna	Casement, louver	0	0	Casement	75% casement, 25% louvers
Nnamdi Azikiwe Library University of Nigeria Nsukka	Projected	Projected	Projected	Projected	100% projected
Federal University of Technology Minna Bosso Campus Library	Sliding	Sliding	Sliding	Sliding	100% sliding
IBB Library Federal University of Technology Minna Gidan Kwano Campus	Projected	Projected	Projected	Projected	100% projected
Francis Idachaba Library, University of Agriculture Makurdi	Projected	Projected	Projected	Projected	100% projected
Hezekiah Oluwasanmi Library, Obafemi Awolowo University Ile-Ife	Louver	Louver	Louver	Louver	100% louver
Kogi State Polytechnic Lokoja Library Lokoja	Sliding	Sliding	Sliding	Projected	75% sliding, 25% projected

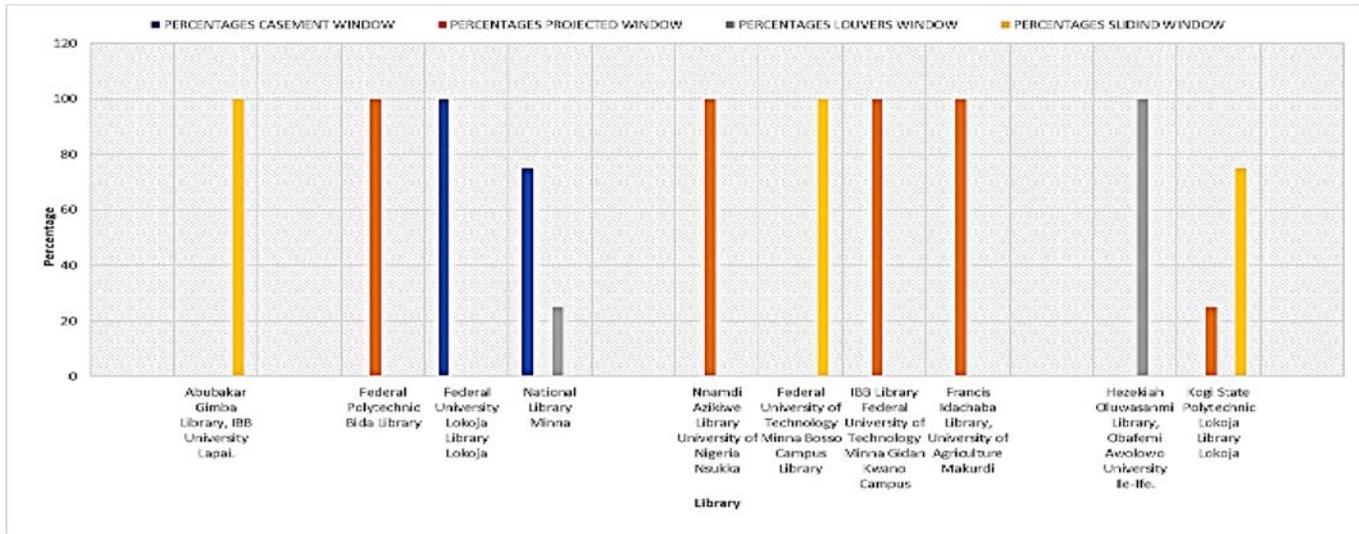


Figure 2 : A Window types used in the library hardcopy

Table I shows the type of windows used in the studied libraries. The bar chart in figure 2 reveals that Abubakar Gimba Library IBB university Lapai and Federal University of Technology library Minna Bosso campus used 100% sliding windows for the reading areas, while Federal University Lokoja Library Lokoja used 100% casement windows. 100% projected windows used at Federal Polytechnic Bida Library, Nnamdi Azikiwe Library University of Nigeria Nsukka, IBB Library Federal University of Technology Minna Gidan Kwano Campus, and the Francis Idachaba Library University of Agriculture Makurdi. Then, the National library Minna used 75% casement and 25% louvres windows. Hezekiah Oluwasanmi Library Obafemi Awolowo University Ile-Ife use 100% louvre windows. Finally, Kogi State Polytechnic Library, Lokoja used 75% sliding windows and 25% projected.

Therefore, the implication is that natural ventilation tends to be more effective at Federal Polytechnic Bida Library, Nnamdi Azikiwe Library University of Nigeria Nsukka, IBB Library Federal University of Technology Minna Gidan Kwano Campus, and the Francis Idachaba Library University of Agriculture

Makurdi, because of their extensively use of projected windows. Hezekiah Oluwasanmi Library, Obafemi Awolowo University Ile-Ife extensive use of louvre windows. Again, natural ventilation was next at National library Minna and Federal University Lokoja Library Lokoja due to the use of casement windows.

Meanwhile, research has shown that for adequate natural ventilation in the building, casement and projected windows are more advisable (Anunobi, Adedayo, Oyetola, Siman, & Audu, 2015). These are the windows that can completely open, unlike sliding windows, the scenario is discouraging.

B. Identification of Openings

Based on the fieldwork, the openings that influenced natural ventilation observed from the selected libraries are; clerestory windows, door openings, screen walls, and others.

Therefore, table II below shows the identification of various openings as observed from the selected libraries.

TABLE III
IDENTIFICATION OF OPENINGS PRESENTS IN THE STUDIES LIBRARIES

Names of library	Clerestory windows	Door openings	Screen walls	Others	Total
Abubakar Gimba Library IBB University Lapai	1	1	1	1	4
Federal Polytechnic Bida Library	1	1	1	1	4
Federal University Lokoja Library Lokoja	1	1	0	1	3
National Library Minna	1	1	0	1	3
Nnamdi Azikiwe Library University of Nigeria Nsukka	0	1	1	1	3
Federal University of Technology Minna Bosso Campus Library	0	1	0	1	2
IBB Library Federal University of Technology Minna Gidan Kwano Campus	1	1	1	1	4
Francis Idachaba Library, University of Agriculture Makurdi	1	1	0	1	3
Hezekiah Oluwasanmi Library, Obafemi Awolowo University Ile-Ife	1	1	0	1	3
Kogi State Polytechnic Lokoja Library Lokoja	1	1	0	1	3
Total	8	10	4	10	32

Note

- 1 - Available
- 0 - Not available

Figure 3 shows that there are other openings like the dwarf wall, archway apart from windows that influenced natural ventilation in the libraries. That is, Abubakar Gimba Library IBB University Lapai has some openings such as clerestory windows, door openings, screen walls, and other openings that influence the circulation of natural ventilation. Again, from the bar chart in figure 3, Federal polytechnic library Bida, has other openings apart from windows that influenced natural ventilation. The openings are clerestory windows, doors, screen walls, and other openings. These various openings in the library encourage more circulation of natural ventilation in the library.

Also, figure 3, it was revealed that Federal University Lokoja Library Lokoja, has door openings and other openings that help in the circulation of natural ventilation. The restriction is that it has no clerestory windows which would have aided more natural ventilation in the library.

National library Minna has clerestory windows, doors opening, and other openings that help in the circulation of natural ventilation. The problem in the National library Minna is that being a non-purpose building the courtyard is blocked thereby restricting natural ventilation.

The Nnamdi Azikiwe Library University of Nigeria, Nsukka has door openings, screen walls and other openings that aided natural ventilation in the library. These openings help in the adequate circulation of

natural ventilation though it does not have clerestory windows which reduce the performance.

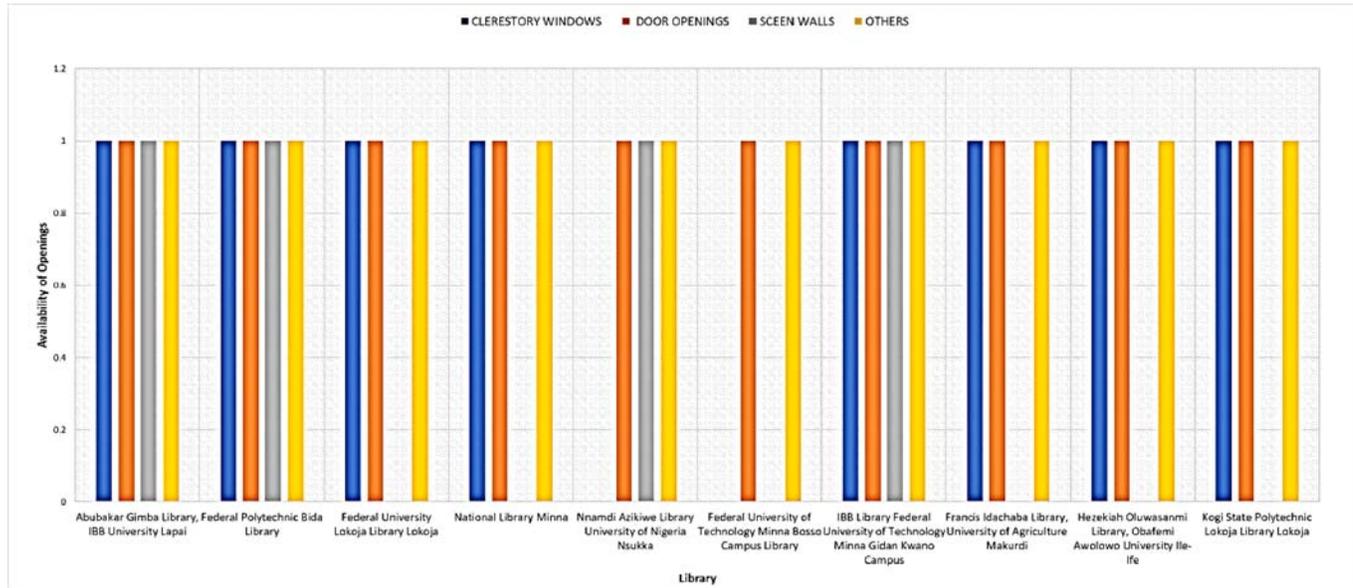


Figure 3 : Identification of library openings

Federal University of Technology Minna Bosso campus library has clerestory window only at the main entrance, door openings and other openings. These various openings help in aiding natural ventilation in the library. Meanwhile, the absence of clerestory windows in the reading areas restricts the performance of natural ventilation in the library.

Furthermore, in figure 3, shows that IBB library Federal University of Technology Minna, Gidan Kwano campus has more openings that encourage natural ventilation. The openings apart from openings, such as windows, doors, screen walls, the window height serve as clerestory windows, and other openings make the circulation of natural ventilation more effective. Therefore, natural ventilation is more encouraged in the library because of the large number of openings.

The Francis Idachaba Library University of Agriculture Makurdi has doors and other openings apart from window openings that help in encouraging natural ventilation. However, clerestory windows due to the height of the window are considered available,

but there is no screen wall; therefore, natural ventilation maybe reduced in the library.

It also reveals that Hezekiah Oluwasanmi Library Obafemi Awolowo University Ile-Ife has doors openings and other openings apart from window openings that encourage circulation of natural ventilation in the library. Meanwhile, the library has no screen walls that would have encouraged the circulation of more natural ventilation. Therefore, natural ventilation is discouraged.

Finally, Kogi State Polytechnic library Lokoja has clerestory windows, door openings and other openings that help in the circulation of natural ventilation. Natural ventilation is very encouraged in the library even though it has no screen wall, but because of the small span of the library.

C. Uses of Court Yard

The availability of courtyard in building especially in a wide- span building is a strategy of passive ventilation (Dunham, 1961; Rajapaksha, Nagai, & Okumiya, 2003) this study also evaluate the

application of courtyard in the study buildings as presented in table III.

Figure 4 reveals that six (6) out of ten (10) libraries selected use courtyard to enhance natural ventilation, while the remaining four (4) do not use the courtyard.

TABLE IIIII
THE SIZE OF COURTYARDS PRESENT IN THE LIBRARIES

Names of library	Courtyard 1(m)	Courtyard2(m)	Total Area
Abubakar Gimba Library, IBB University Lapai	34.45 x 18.00 620.1m ²	0	620.10m ²
Federal Polytechnic Bida Library	0	0	0
Federal University Lokoja Library Lokoja	0	0	0
National Library Minna	0	0	0
Nnamdi Azikiwe Library University of Nigeria Nsukka	24.00 x 12.00 288.00 m ²	24.00x12.0 288.00 m ²	576.00m ²
Federal University of Technology Minna Bosso Campus Library	4.40 x 12.00 52.80 m ²	2.40 x 6.20 14.88 m ²	67.68m ²
IBB Library Federal University of Technology Minna Gidan Kwano Campus	8.60 x 8.90 76.54 m ²	15.10 x 15.10 228.01 m ²	304.55m ²
Francis Idachaba Library, University of Agriculture Makurdi	0	0	0
Hezekiah Oluwasanmi Library, Obafemi Awolowo University Ile-Ife	28.00 x 18.00 504	0	504 m ²
Kogi State Polytechnic Lokoja Library Lokoja	7.20 x 4.20	0	30.24 m ²

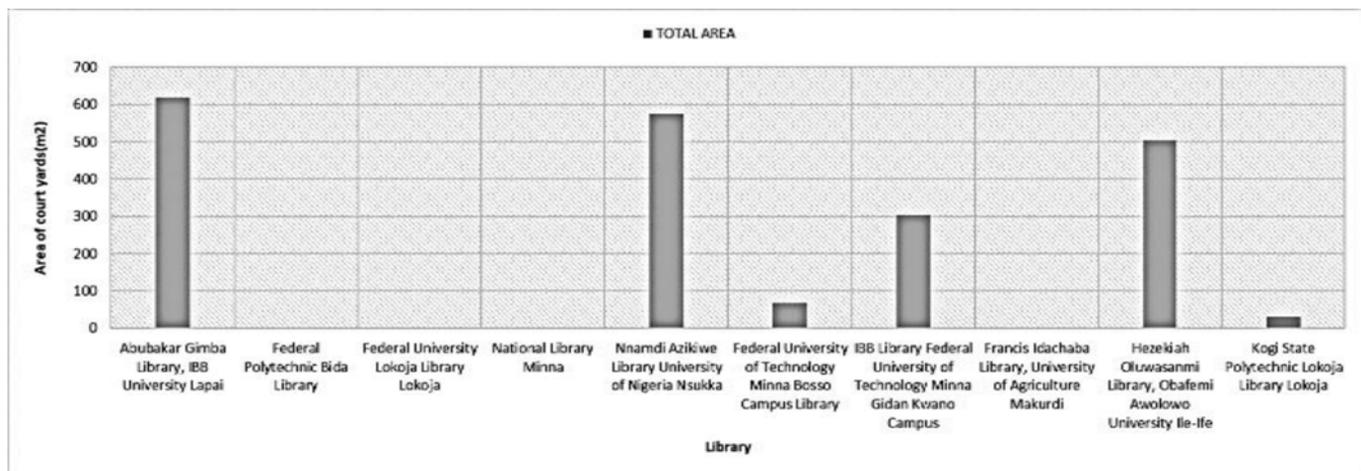


Figure 4 : Courtyards opening areas in the libraries

Abubakar Gimba Library Ibrahim Badamasi Babangida University Lapai has the highest courtyard

opening areas of 620.10m² and natural ventilation is very much encouraged because of large courtyard

opening areas in the library. Also, Nnamdi Azikiwe Library University of Nigeria Nsukka has 576m² courtyard opening, followed by Hezekiah Oluwasanmi Library Obafemi Awolowo University Ile-Ife with 504 m² courtyard opening areas and the availability of double courtyards in the library make the circulation of natural ventilation more effective. More so, IBB library Federal University of Technology Minna, Gidan Kwano campus has 304.55m² of the court yard, and the use of double courtyards in the library also makes the circulation of natural ventilation effective while Federal University of Technology Minna Bosso Campus Library has

67.68m² courtyard opening area which makes natural ventilation slightly encouraged and Kogi State Polytechnic Lokoja Library Lokoja has 30.24 m² which also encourage natural ventilation.

D. Uses of External Shading Devices

External shading is also an architectural strategy for enhancing thermal modification of an indoor environment (Freewan, 2014). These devices usually shade the building from direct solar radiation as well as cooling the inlet air; hence the air temperature of the building interior (Hien & Istiadji, 2003).

TABLE IV
THE USE OF EXTERNAL SHADING DEVICES IN THE LIBRARIES

Names of library	External Shading Devices			
	Vertical	Horizontal	Vertical & horizontal	Non
Abubakar Gimba Library, IBB University Lapai	●	●	✓	●
Federal Polytechnic Bida Library	●	●	✓	●
Federal University Lokoja Library Lokoja	✓	✓	●	●
National Library Minna	●	●	●	✓
Nnamdi Azikiwe Library University of Nigeria Nsukka	✓	✓	●	●
Federal University of Technology Minna Bosso Campus Library	●	●	●	✓
IBB Library Federal University of Technology Minna Gidan Kwano Campus	●	●	✓	●
Francis Idachaba Library, University of Agriculture Makurdi	✓	✓	●	●
Hezekiah Oluwasanmi Library, Obafemi Awolowo University Ile-Ife	✓	✓	●	●
Kogi State Polytechnic Lokoja Library Lokoja	●	✓	●	●
TOTAL	4	5	3	2

Note:

- ✓ Available
- Not Available

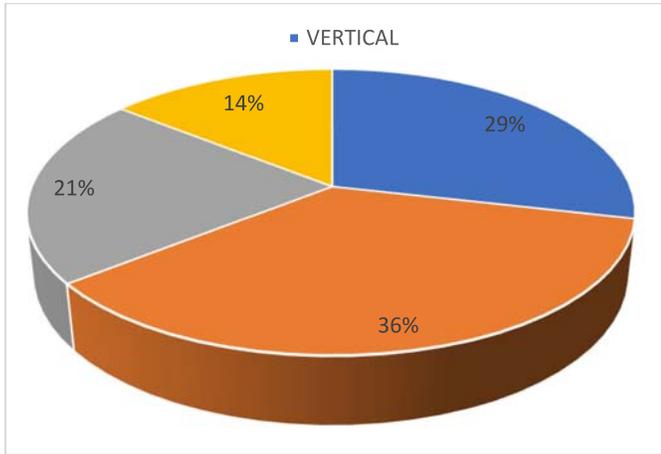


Figure 5 : The use of external structural shading devices in the libraries

Table IV presents the various shading device used in the studied libraries. The pie chart in the figure 5 reveals that 29% of the studied libraries use external vertical structural shading devices as a way of deflecting solar radiation in the libraries hence natural ventilation enhancement while 36% use horizontal shading devices to deflect solar radiation. Then, 21% use both vertical and horizontal shading devices to deflect solar radiation. Finally, 14% do not use any external shading devices.

Therefore, the implication is that external structural shading devices are used in buildings to deflect solar radiation and thereby to increase the chances of natural ventilation in the building. Then, the libraries without external structural shading devices have discouraged natural ventilation. Abubakar Gimba Library IBB University Lapai, IBB library Federal University of Technology Minna, Gidan Kwano Campus and Federal polytechnic library Bida make use of combined vertical and horizontal external shading devices to deflect the intensity of solar radiation and in turn increase the chances of circulation of desirable ventilation.

E. The orientation of the Libraries

The orientation of buildings has a significant effect on the natural ventilation of buildings (Al-Tamimi, Fadzil, & Harun, 2011; Hamdy & Fikry, 1998). Research shows that the standard orientation of building for better natural ventilation in the study area is North-South (NS) orientation of building length, while the East-West (EW) orientation required more energy for cooling the buildings and therefore, buildings should be oriented to take maximum advantages of wind direction. These imply that, for enhanced natural ventilation, the longer side of the building with architectural openings should facing north-south orientation, while the shorter side should be facing east-west direction.

The orientation of the libraries is tabulated based on the orientation of the longer sides of the case studied libraries and presented in table V.

TABLE V
THE ORIENTATION OF THE STUDIED LIBRARIES

Names of library	NS	EW
Abubakar Gimba Library, IBB University Lapai	✓	●
Federal Polytechnic Bida Library	●	✓
Federal University Lokoja Library Lokoja	✓	●
National Library Minna	✓	●
Nnamdi Azikiwe Library University of Nigeria Nsukka	✓	●
Federal University of Technology Minna Bosso Campus Library	●	✓
IBB Library Federal University of Technology	✓	●

Minna Gidan Kwano Campus		
Francis Idachaba Library, University of Agriculture Makurdi	✓	●
Hezekiah Oluwasanmi Library, Obafemi Awolowo University Ile-Ife	✓	●
Kogi State Polytechnic Lokoja Library Lokoja	✓	●
Total	8	2

Note

- ✓ - Available
- - Not Available

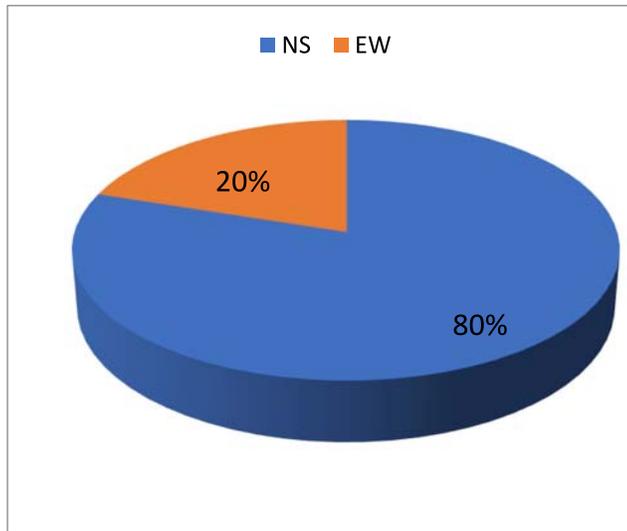


Figure 6 : Orientation of the libraries

The pie chart in figure 6 reveals that 80% of the libraries studied were oriented toward the north-south direction, while 20% oriented east-west direction.

However, the implication is that the majority of the libraries studied have a better orientation. These means that they can take maximum advantage of natural ventilation, only two libraries the Federal Polytechnic Bida Library and Federal University of Technology Minna Bosso Campus Library have poor

orientation, which means they will not be able to take maximum advantage of natural ventilation.

V. CONCLUSION

Natural ventilation is desirable in buildings for human comfort, that is, body cooling, odour removal and structural cooling within the building environment. A study conducted revealed that public libraries in temperate humid climate region of Nigeria could not function efficiently without an artificial source of ventilation and lighting. This source of ventilation aside its economic disadvantages, it not reliable and has sustainability problems. However, natural ventilation is more efficient and more reliable as well as consume less energy as compared to other types of ventilation.

The study evaluates the application of natural ventilation architectural strategies in libraries within the hot -humid climatic region, to solving the problem of poor natural ventilation in the libraries. The data collections for the research are of two types; the primary data which are obtained directly from case studies: observation schedules, photographs and sketches of the libraries and the secondary data which are the information obtained from textbooks, journals, magazines and internet resources.

Then, ten (10) libraries selected at random in the study area derived from both institutional and public libraries. The openings in the buildings that serve as the sources for natural ventilation such as window types, clerestory windows, door openings, courtyard and other openings in the building were the variables. The second was observation schedule element influencing natural ventilation in the libraries. They are; the use of external structural shading devices and orientation of the libraries. Therefore, each of these was measured against the selected libraries. The data obtained for the research analysed descriptively using Microsoft excel 2016. The used of tables, bar charts

and pie charts was applied for data and results presentation.

Then, based on the case studies, literature review and the analysis, it was observed that natural ventilation tend to be more effective at Federal polytechnic library Bida, the Nnamdi Azikiwe Library University of Nigeria Nsukka, IBB Library Federal University of Technology Minna Gidan Kwano Campus and Francis Idachaba Library, University of Agriculture, because of their extensively use of projected windows.

The research indicates that 29% of the studied libraries use external vertical structural shading devices while 36% use horizontal shading devices, 21% use both vertical and horizontal shading and 14% do not use any external shading devices. More so 80% of the libraries studied are oriented toward north-south (NS) direction, while 20% oriented east-west (EW) direction. Therefore, the majority of the libraries studied are having proper orientation, which means that they take maximum advantage of natural ventilation

Adequate natural ventilation in the libraries is achievable with proper orientation of the building, proper design of building internal spaces and proper position of window openings and the use of projected windows with clerestory.

VI. RECOMMENDATIONS

The following are the design recommendation for effective natural ventilated designed library.

1. Cross ventilation should be encouraged when designing the naturally ventilated library.
2. Large openings areas should be encouraged when designing a library that carter for natural ventilation.
3. More window openings positioned at the windward side of the building.

4. The uses of clerestory or high-level windows should be encouraged in the library design.
5. The projected window should be encouraged and be accessible, operable by the library users.
6. The reading areas location should take maximum advantage of natural light and ventilation.
7. For adequate natural ventilation, the span of the spaces should not be too large.
8. The library should be oriented to take maximum advantage of natural ventilation; that is, north-south (NS) orientation is desirable.
9. Further research on the configuration with stalk ventilation and top down ventilation should be carried out to enhanced natural ventilation in the library.

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