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Assessment of Natural Ventilation in Multi-Storey Residential in Abuja, Nigeria

Adedayo S. M.; & Lawal L. A. T
Department of Architecture, School of Environmental Technology, Federal University of Technology, Minna, Nigeria.
adedayooluwaseun79@gmail.com

Abstract
The design of domestic buildings which adopts a purely natural ventilation strategy is now commonplace in many parts of the world, and increasing this strategy has been shown to be viable in city centers as well as 'green field' locations. However, the adoption of natural ventilation in high-rise residential buildings are less common causing environmental problems and cost implications associated with mechanically ventilated buildings. The study is aimed at assessing natural ventilation strategies and ways in which it can be implemented in multi-storey residential buildings. This is to be achieved through it's objectives; to understand the respondents knowledge about natural ventilation, ,to understand the building operation and how it affect proper ventilation in multi storey building, identify and examine other factors that can affect the operation of natural ventilation on the comfort of building occupants. The study will make use of quantitative type of research which includes survey, by making use of questionnaires and fact finding enquires of different kinds, use of journals, book and articles. In this discourse, the issues of natural ventilation and natural ventilation strategies will be explored to bring out their significance in promoting a naturally ventilated building in order to minimize energy consumption and to reduce the reliance on "mechanical" ventilation for a more sustainable environment. These strategies are to be considered before and during design in order to maximize its effect. This paper proposes to significantly enlighten general populace and provide greater awareness of the several benefits gained from a well-ventilated building.

Keywords: natural ventilation, multi-storey, energy, thermal comfort, natural cooling

Introduction

The global rise in urbanization, particularly in Nigeria, has significantly increased energy consumption in buildings. The (IPCC 2014) reports that buildings worldwide contributed to 32% of total energy consumption in 2010, with residential buildings in Africa consuming over 79% of this energy. Specifically in Nigeria, studies by (Ezema et al., 2016), (Adebisi et al., 2008), and (Akinbami and Lawal 2010) found that residential buildings accounted for approximately 78-50.4% of total energy use and electricity consumption. This underscores the importance of addressing energy consumption in residential buildings to mitigate environmental impact.

The high energy consumption in Nigerian residential buildings is attributed to rapid urbanization, climatic conditions, and architects' oversight of climate-conscious design (Adebisi et al., 2008). Nigeria's tropical climate, characterized by high temperatures, leads to heat buildup in spaces, causing significant thermal stress for occupants (Gut and Ackerknecht, 1993). Architects face the ongoing challenge of preventing and swiftly removing heat accumulation in residential spaces (Ogunsote et al., 2011). (Nwofe, 2014) emphasizes that the majority of energy consumption in Nigerian structures is attributed to active devices like fans and air conditioners used for indoor comfort. However, these devices are deemed uneconomical and contribute to energy crises, increased greenhouse gas emissions, and global warming (Ogunsote et al., 2011). In response to global efforts to reduce energy consumption, there is a growing interest in natural ventilation studies due to its efficiency, effectiveness, zero energy consumption, and economic advantages over mechanical devices (Adegbie, 2013). Given the challenges of high energy costs, low generation, and inconsistent supply in Nigeria, the exploration of natural ventilation for indoor comfort in multi-story buildings in core areas becomes imperative (Nwofe, 2014).

Natural ventilation is a key strategy for enhancing thermal comfort in warm regions, with (Ayinla, 2011) highlighting its potential sufficiency. (Richard, 2011) emphasizes its efficiency in improving indoor air quality and being a cost-effective means of achieving thermal comfort. The Energy Commission of Nigeria 2003 found that final energy costs for naturally ventilated buildings are 40% less than conditioned buildings. Improved indoor conditions through natural ventilation can enhance occupant productivity and reduce healthcare costs (Fisk and Rosenfeld, 1997). (Stoakes,

2009) notes that considering natural ventilation early in the design process incurs minimal costs, making it a crucial consideration from the outset.

This study in Abuja aims to assess natural ventilation in multi-storey buildings, with objectives including gauging respondents' knowledge about natural ventilation, understanding building operations affecting ventilation, and examining factors influencing its effectiveness. The research emphasizes the importance of natural ventilation for reducing energy consumption in Nigerian residential buildings and enhancing indoor air quality. The study underscores considerations for natural ventilation across the building lifecycle, from pre-design to construction and post-construction phases.

LITERATURE REVIEW

Ventilation

Ventilation, as highlighted by (Awbi, 1991), involves bringing outdoor air into a building or room, distributing it internally, and serves the crucial purpose of providing healthy air by diluting and removing pollutants for improved indoor air quality.

Natural forces, such as wind and thermal buoyancy, drive outdoor air through purpose-built openings like windows, doors, solar chimneys, wind towers, and trickling ventilators. Factors like climate, building design, and human behavior impact natural ventilation. Well-designed and maintained natural ventilation systems offer advantages over mechanical ones, presenting a appealing method for reducing energy use and costs while ensuring a healthy indoor environment. With increased awareness of energy's environmental impacts, architects should prioritize efficient natural ventilation in building design.

The Three Major Design Elements of Natural Ventilation

(i) Site Design — building location, layout, building orientation, landscaping

(ii) Building Design — type of building, building function, building form, envelope, natural ventilation strategy, internal distribution of spaces and functions, thermal mass, heating, ventilation and air-conditioning if it exists; and

(iii) Vent Opening Design — position of openings, types of openings, sizing of openings, control strategy.

Site Design

Site design involves blending buildings with the landscape, allowing minor changes with environmental considerations. To optimize natural ventilation, leverage the site's natural airflow patterns. For multiple buildings, it is best to ensure exposure to South-West winds, avoiding North-East winds in hot climates. Building form and orientation should enhance negative pressures in airflow wakes (Aynsley et al., 1977).

Building design

In simple buildings, factors like roof design, aspect ratios, and the use of overhangs, wind walls, and recessed spaces contribute to effective natural ventilation. For larger and complex structures, computational fluid dynamics is recommended for optimal design and to prevent cold draughts (Fluent, 2003). Compact structures with thoughtful internal space distribution and large windows on the windward side enhance airflow.

Windows/Glazing

The building envelope, particularly windows, doors, and skylights, influences heat gain/loss and interior wind flow. Windows, defined as openings allowing light and air, play a significant role in the thermal performance of the building envelope (Carmody et al., 1996). Glazed windows, as described by (Al-Saadi, 2006) and (Datta, 2001), provide natural light, reduce structural load, and enhance aesthetics. Well-shaded and positioned windows can notably reduce a building's energy usage (Szokolay, 2004). The window-to-wall ratio (WWR) is crucial for thermal conditions within a building (Carmody et al., 1996).

(Bokel, 2007) studied window position and size effects on energy demand, suggesting an optimal window-to-wall ratio (WWR) of about 30% in the top half of the facade. WWR between 20% and 40% is acceptable, with larger ratios having minimal impact on lighting loads. Also suitable glazing types, sizes, positions, and orientations for minimizing the sun's impact on residential building interiors are important factors that should be considered.

METHODOLOGY

Research methodology serves as a scientific approach to address research problems (Kothari and Gaurav, 2014). In this project, a quantitative research method was chosen for its structured, statistical nature, allowing the collection of numerical data to measure variables objectively and conclusively. This approach facilitates statistical analysis for validating hypotheses.

The study collected primary data through direct observation and questionnaires distributed to users of selected multi-storey residential buildings (124 questionnaires in total). The questionnaires covered demographic, socioeconomic, building operations, and building characteristics. Secondary data was gathered from various sources, including conference proceedings, journals, books, dissertations, projects, seminar papers, drawings, and reliable internet sources.

RESULT AND DISCUSSION

Table 4.0.1. Summary of the reliability statistics for the questionnaire survey

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.557	0.54	21

Source: Survey Data, 2022

The Cronbach alpha based standardized items obtained is 0.557, which means that the data is reliable**.**

Demographic data of the respondents

This section describe the demographic information of the respondents in the study area. These include gender, age bracket, academic level etc

The demographic distribution of the respondents is shown in table 4.1.1

The survey showed a higher participation of males (65.3%) compared to females (34.7%). The majority of respondents (93.5%) were in the 18-30 age bracket, with a smaller proportion (6.5%) aged between 45-60 years. Regarding education, 73.4% had a bachelor's degree, while 14.5% held a master's degree.

Table 4.1.1 Demographic distribution of the respondents

Variable	Frequency	Percent
Gender		
Male	81	65.3
Female	43	34.7
Total	124	100
Age range		
18-30 years old	116	93.5
45-60 years old	8	6.5
Total	124	100
Highest academic qualification		
High School	14	11.3
Bachelor	91	73.4
Master	18	14.5
Doctor	1	0.8
Total	124	100
The floor of your home is?		
first floor	100	80.6
Middle section	11	8.9
Upper section	13	10.5

Total	124	100
How many months have you occupied this building		
Less than 6 months	14	11.3
6-12 months	18	14.5
12-18 months	21	16.9
More than 18 months	71	57.3
Total	124	100
The number of households in your current home is?		
0-5	70	56.5
05-10	42	33.9
10- above	12	9.7
Total	124	100

Source: Survey Data, 2022

The survey revealed that a significant portion of respondents (80.6%) have a first floor in their homes, with 10.5% on upper floors and 8.9% on middle floors. Regarding the duration of occupancy, 57.3% have lived in the building for more than 18 months, 16.9% for 12-18 months, and 11.3% for less than 6 months. In terms of household size, 56.5% indicated 0-5 members, and 33.9% indicated 5-10 members. A majority (63.7%) described their knowledge of natural ventilation as very good. Respondents generally found the natural ventilation systems in their buildings to be adequate, with 46% saying often and 44.4% saying sometimes. About 58.1% indicated that all rooms are cross-ventilated, while 41.9% said no. Additionally, 40.3% sometimes use mechanical ventilation, while 34.7% often use it.

Table 4.1.1 cont

How would you describe your knowledge of natural ventilation		
No knowledge	1	0.8
Fair knowledge	44	35.5
Very good knowledge	79	63.7
Total	124	100
Adequacy of natural ventilation systems in the building?		
Never	2	1.6
Rarely	10	8.1
Often	57	46
Sometimes	55	44.4
Total	124	100
Are all the rooms cross ventilated		

Yes	72	58.1
No	52	41.9
Total	124	100
How frequent do you use mechanical ventilation?		
Always	10	8.1
Often	43	34.7
Sometimes	50	40.3
Rarely	21	16.9
Total	124	100
Is the building shaded in anyway?		
Yes	55	44.4
No	69	55.6
Total	124	100
window types in the rooms		
Slide hung window(i.e casement type	36	29
Top hung window (i.e projected type)	10	8.1
Sliding window	65	52.4
Louvers window	13	10.5
Total	124	100
Proffered ventilation system		
Natural wind	102	82.3
Mechanical	22	17.7
Total	124	100

Source: Survey Data, 2022

Regarding shading, 55.6% of respondents (69) indicated that the building was not shaded, while 44.4% (55) stated otherwise. In terms of window types, 52.4% (65) used sliding windows, 29% (36) used slide-hung windows, and 8.1% (10) used top-hung windows (projected type). The majority (82.3%) preferred natural wind as their ventilation system, with only a small percentage favoring mechanical systems.

Building Operations

The majority of respondents (91.9%) cook in a separate kitchen, with only 4.8% cooking inside their rooms. For cooking, 87.1% use gas, and 10.5% use electric cookers. The majority (91.9%) stated that none of their family members smoke, while 8.1% indicated otherwise. Regarding indoor activities, 58.1% don't dry clothes inside, and 41.9% do. For lighting, 83.9% use electricity, and 9.7% use solar energy.

Table 4.2.1 Respondents view on building operation

Variable	Frequency	Percent
Where do you carry out your cooking?		
Inside the room	6	4.8
Separate room in the house (I.e Kitchen	114	91.9
Separate building outside the house	4	3.2
Total	124	100
Which of the following do you use in the house for cooking?		
Electric cooker	13	10.5
Gas	108	87.1
Charcoal	1	0.8
Kerosene	2	1.6
Total	124	100
Do you or anyone in the family smoke in the house?		
Yes	10	8.1
No	114	91.9
Total	124	100
Do you or anyone dry clothes in the house?		
yes	52	41.9
no	72	58.1
Total	124	100
Please indicate your main source of light in the house at night		
Eletricity	104	83.9
Generator	6	4.8
Solar	12	9.7
Lamp	2	1.6
Total	124	100

Source: Survey Data, 2022

Chi-Square Test On Preffered Ventilation System And Building Characteristics

4.3.1 Proffered ventilation system * Material used for wall finishing used for wall finishing

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.533a	3	0.317
Likelihood Ratio	3.359	3	0.34
Linear-by-Linear Association	0.49	1	0.484
N of Valid Cases	124		

Source: Survey Data, 2022

In these results, the Pearson chi-square statistic is 3.53 and the p-value = 0.317. The likelihood chi-square statistic is 3.359 and the p-value = 0.34. Therefore, at a significance level of 0.05, we cannot conclude that the association between preferred ventilation system and material used for wall finishing is statistically significant. Therefore, the material used for wall finishing have nothing to do with the preferred ventilation system.

Proffered ventilation system * Material used for floor finishing

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.062a	3	0.005
Likelihood Ratio	13.678	3	0.003
Linear-by-Linear Association	2.428	1	0.119
N of Valid Cases	124		

In these results, the Pearson chi-square statistic is 13.062 and the p-value = 0.005. The likelihood chi-square statistic is 13.678 and the p-value = 0.003. Therefore, at a significance level of 0.05, we can conclude that the association between preferred ventilation system and material used for floor finishing is statistically significant. Therefore, the material used for floor finishing have something to do with the preferred ventilation system.

Proffered ventilation system * Material used for Ceiling finishing

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.233a	2	0.199
Likelihood Ratio	2.964	2	0.227
Linear-by-Linear Association	1.742	1	0.187
N of Valid Cases	124		

In these results, the Pearson chi-square statistic is 3.233 and the p-value = 0.199. The likelihood chi-square statistic is 2.964 and the p-value = 0.227. Therefore, at a significance level of 0.05, we cannot conclude that the association between preferred ventilation system and material used for ceiling finishing is statistically significant. Therefore, the material used for ceiling finishing have nothing to do with the preferred ventilation system.

Building Envelope Characteristics

A great number of the respondents 117 (94.4%) uses cement block as the material used for wall finishing, while a very few of the respondents 2 (1.6%) uses wood and zinc

respectively. A good number of the respondents 105 (84.7%) also uses tile for their floor finishing follow by cement 9 (7.3%) and carpet/rug 8 (6.5%). Majority of the respondents 65 (52.4%) uses ceiling board for their ceiling finishing, while 57 (46%) of the respondents uses abestors.

Table 4.4.1 Respondents view on the building envelop characteristics

Variable	Frequency	Percent
Material used for wall finishing used for wall finishing		
Earth/mud	3	2.4
Wood	2	1.6
Cement block	117	94.4
Zinc	2	1.6
Total	124	100
Material used for floor finishing		
Tile	105	84.7
Wood	2	1.6
Cement	9	7.3
Carpet/Rug	8	6.5
Total	124	100
Material used for Ceiling finishing		
Abestors	57	46
Carton	2	1.6
Ceiling board	65	52.4
Total	124	100

Source: Survey Data, 2022

CONCLUSION AND RECOMMENDATON

According to the study results, there is little awareness on natural ventilation strategies and operations in builidngs. Therefore, it is critical to create guidelines that incorporate these strategies in buildings (multi-storey buildings) to assist architects, builders, and other professionals in the building industry that can be considered before, during and after design/construction. Strategies that include; location of openings, opening positions, number and sizes of openings, opening types, proper landscape, building design, spacing (buildings position in relation to one another), proper orientation etc.

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