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Assessment of Residents' Satisfaction with Natural Ven tilation in Mass Housing Schemes, Ibadan, Southwest, Nigeria

Ajani Joel Akinsanya and Odunjo Oluronke Omolola

Department of Architecture, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

Corresponding author: ooodunjo@lautech.edu.ng

ABSTRACT

This study assessed residents' satisfaction with natural ventilation in Owode mass housing project in Ibadan, southwest, Nigeria. The location was borne out of the fact that the city is a traditional urban centre with phenomenal population growth as well as industrialisation. Systematic random sampling was used in selecting one hundred and sixty three houses and the questionnaire and observation formed the basic instruments for data collection which were administered to respondents to collect information on the physical characteristics of the houses, mechanisms used for natural ventilation as well as residents' satisfaction with natural ventilation in the houses. Giovanni mathematical model was used to measure the efficiency of ventilation in relation to window openings of the houses. Descriptive statistical analysis was employed in the presentation of the findings. Flat bungalow (75.0%) was prominent in the area and they were built with sandcrete block (84.6%). Mechanisms used for natural ventilation was majorly window (78.0%) and casement window (36.5%) constituted the bulk of the windows. Analysis shows that 47.2% of the living room had one window as well as bedroom (71.2%). However, size of living room window (47.2%) was 1.2X 1.4m as well as bedroom (66.9%). Also, 69.3% windows of living room were sin gle sided and faced northeast direction, while 73.6% windows of bedroom were single sided and also faced northeast direction. Results of Giovanni mathematical model shows that the average ventilation obtained in the houses with louvre, casement, projected and sliding windows were 0.33m/s; 0.40m/s; 0.35m/s and 0.21m/s and therefore, none of the spaces satisfied the ventilation comfort of 0.5-1.5 m/s for warm, humid climate and residents were not satisfied with louvre (p= 0.059); casement window (p= 0. 065) and sliding windows (p=0.0780).The study suggests among others that there should be adoption of louvered or casement window of adequate sizes as well as soft landscape elements in the houses in order to make them conducive.

Key words: Residents' satisfaction, Natural ventilation, Houses, Mechanisms for ventilation, Window

Introduction

Global campaign against increasing demand for energy consumption has gained tremendous interest of both policy makers and researchers in the recent years. Studies abound on residential thermal comfort and the need to ensure adequately ventilated buildings to avert attendant effects ranging from health to environmental challenges (Akande and Adebamowo, 2010; Rajasekar and Ramachandraiah, 2010; Sakka*et al*, 2010; Fang*et al*, 2012;*Bojićet al*, 2013; World Bank, 2013; Haruna *et al*, 2014). The issues raised by the studies include efficiency of mechanically driven ventilation, contribution of mechanical devices for thermal comfort to global warming and environmental changes, awareness of thermal discomfort in buildings under various environmental conditions, building energy simulations, effects of construction materials on optimum ventilation, subjective as well as experimental evaluation of thermal comfort characteristics among others; hence, there is no succinct concern and investigation into conscious effort towards utilisation of natural ventilation for thermal comfort and satisfaction in the design process of housing.

However, the incidence of population increase has created severe housing problems in cities, resulting in overcrowding and inadequate dwellings (Odunjo, 2014). Rapid population growth creates problems toward adequate and efficient supply of natural ventilation for the city inhabitants. The situation is so pathetic such that, overcrowding, slum and substandard housing as well as unhealthy and poor environmental conditions are expressions of this problem. Thus, access to decent housing is a challenge in a developing country like Nigeria (Odunjo *et al,* 2021).

Housing provision in most nations of the world is made through a blend of public and private sector initiatives. However, modern design concepts and ideas have been greatly influenced by the emergence and increasing involvement of private sector in housing delivery and higher taste for technological innovations. Thus, this has introduced gradual substitution of nature-driven design (green building design) to mechanical-oriented philosophies in building design and construction. Spengler and Chen (2000) argued that current guidelines for green buildings are cursory and inadequate for specifying materials and designing ventilation systems to ensure a wholesome indoor environment, i.e. a “healthy building,” by design. The multidimensional scale of these deviances are evidence of high energy demand to power and sustain houses leading to high cost of maintenance, environmental degradation and health related issues among others.

The purpose of ventilation is to provide fresh air for comfort and ensure healthy indoor air quality by diluting contaminants. Historically, people have ventilated buildings to provide source control for both combustion products and objectionable odours (Sherman, 2004) and natural ventilation has been argued to be an energy efficient alternative for reducing the energy use in buildings, achieve thermal comfort, and maintain a healthy indoor environment (Allocca *et al*, 2003). In other words, the increased use of mostly fossil-based energy leads to atmospheric pollution and global warming. Typically, the energy cost of a naturally ventilated building is 40% less than that of an air-conditioned building.

Willmert (2001) and Clarke (2001) observed that natural ventilation has become a new trend in building design in architectural community and has been used in many types of buildings. As a result, there is an urgent need for sustainable housing development towards naturally ventilated residential buildings which are environmental friendly in order to give good and positive impact to its inhabitants against prevailing problems of mechanical ventilation system, such as need for space, increase rate of energy consumption, noise generation within and outside of buildings and difficulties in cleaning and maintenance. Consequently, drawing upon contemporary accounts of inner city asthma rates and cases of sick buildings, the building professions need more than cursory and inadequate guidance to incorporate indoor air quality considerations into their "healthy building" design. This therefore, is the focus of this study, to assess residents' satisfaction with natural ventilation in Owode mass housing project in Apata, Ibadan with a view to suggesting measures that will improve the living standards of the inhabitants of the houses.

Conceptualization and Review of Literature

Natural ventilation is defined as using passive strategies to supply outdoor air to a building's interior for ventilation and cooling (Ghiaus *et al*, 2005; *USGBC, Cascadia Chapter 2010)*. It is created by pressure differences between the outside and the inside of a building. The 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 like that of Nigeria; it merely requires a low outdoor wind speed to create adequate indoor air speed. The air temperature differences are usually not high enough to generate any effective air movement.

The main purpose of natural ventilation as a passive cooling strategy is to achieve high indoor air velocities with the air that has appropriate temperature and relative humidity. The factors that influence it are outdoor environment and building component. It is known that landscape elements such as trees and water bodies can reduce air temperature, while hard-surface elements such as concrete grounds raise the air temperature.

Natural ventilation is essential in buildings because rapid urbanization has led to a significant increase in building energy usage, which accounts for nearly one-third of the total primary energy consumption worldwide (Chen *et al*, 2017). As a key solution to the efficient operation of buildings, natural ventilation plays a significant role in maintaining an acceptable indoor environment (Haase and Amato, 2009; Chenari *et al*, 2016). The benefits of natural ventilation include , but are not limited to, improved indoor thermal comfort, reductions in occupant illness associated with indoor environmental quality (IEQ), and increased work productivity with low energy consumption and greenhouse gas (GHG) emissions (Dimitroulopoulou, 2012; Jomehzadeh *et al*,2017; Stabile *et al*, 2017).

Methodology

Both primary and secondary data were used for the study. Primary data collection involved first – hand information on the problem from the field through the use of structured questionnaire and observation in order to provide comprehensive explanation of the subject of investigation thereby increasing trust in the validity of the research findings and conclusion. Secondary data was collected through literature review.

The questionnaire was designed to extract relevant information from the houses. It thus examined the physical characteristics of houses such as house type, mechanisms used for natural ventilation, types of window as well as orientation of houses. Others include efficiency of natural ventilation within the living room and bedroom of the houses. Living room and bedroom of the houses were chosen because this is where people stay most time of the day.

The sampling frame was Owode mass housing project or estate in Apata, Ibadan. Using the road network of the estate, the area was segregated into six zones and the choice of zone was based on the size of the estate since it was basically characterized by less dense development. In order to achieve a good and reliable sample frame, notable area in which their boundaries were obvious was used as a criterion for the selection of zone. The zones include first gate, second gate, northern side, southern side, central and Anglican church side of the estate.

Systematic random sampling was used for the study. The first house was chosen at random, while others were chosen at interval of five (5) along each street. In all, a total of one hundred and sixty-three (163) houses were chosen for questionnaire administration thereby, representing 5% of the total house population as shown in Table 1. A set of questionnaire was administered on the household heads and was harvested on the spot.

Table 1: Sample Size

Zone	Number of Houses	Number of Questionnaire Administered
First gate	357	18
Second gate	752	38
Northern side	430	22
Southern side	400	20
Central	632	32
Anglican church side	689	34
Total	**3260**	**163**

Source: Authors' Fieldwork (2023)

The data obtained from the study were analysed with frequency counts and percentages. Giovanni mathematical model was used to measure the efficiency of ventilation in relation to window openings of the building. The mathematical model is an empirical one that is based on simplified methods for the estimation of air velocity inside naturally ventilated buildings.

Thus, the method was chosen because it is used to measure the efficiency of natural ventilation in warm humid climate. The model established the relationship between average indoor and outdoor air velocity with the window placed perpendicularly to each other and the formula is:

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

Where: V_i *=average indoor velocity*

x =the ratio of window area to wall area

V_o *= the outdoor wind velocity*

Analysis and Discussion of Findings

(i)Building Characteristics

The prominent house type in the area was flat bungalow (75.0%) which supports the submission of Aribigbola (2000 and 2011); Odunjo (2014); Odunjo, Okanlawon, Ayinla and Ayanda (2015) as well as Oladimeji (2023) that in Nigeria, people prefer the flat type building for privacy reason, compared to other types of building. However, this was followed by flat storey building (13.0%); duplex (10.0%) and brazilian bungalow (2.0%) as shown in Table 2. More than four-fifths of the buildings (84.6%) were constructed with sandcrete block which is the most prominent building material in Nigeria (Table 3). Burnt brick constituted 11.0%, while mud was 4.4%. However, three-quarter (75.0%) of the residents owned the houses, while only one -quarter (25.0%) were tenants.

Table 2: House Type

Variable	Frequency (N)	Percentage (%)
Flat bungalow	122	75.0
Flat storey building	21	13.0
Duplex	17	10.0
Brazilian bungalow	3	2.0
Total	**163**	**100.0**

Source: Authors' Fieldwork (2023)

Table 3: Building Materials

Variable	Frequency (N)	Percentage (%)
Sandcrete block	138	84.6
Burnt brick	18	11.0
Mud	7	4.4
Total	**163**	**100.0**

Source: Authors' Fieldwork (2023)

(ii)**Mechanisms for Ventilation**

Three mechanisms were used for natural ventilation in the area. These are window, courtyard and landscape elements. More than seven-tenths (78.0%) of the respondents used window; 9.5% respondents used the combination of window and courtyard, while only 12.5% respondents adopted landscape elements. Out of the respondents that utilized window, casement window constituted 36.5%, while louver blade was 31.0%. Also, projected window type was 22.0%, with sliding window being 10.5% (Table 4).

Table 4 : Window Type

Type	Frequency (N)	Percentage (%)
Louver	51	31.0
Sliding	17	10.5
Casement		
Projected	59	36.5
	36	22.0
Total	**163**	**100.0**

Source: Authors' Fieldwork (2023)

Furthermore, number of window as well as size of window in the living room and bedroom was assessed in order to know the extent of natural ventilation provided in the houses. Analysis shows that living room window varies from 1-4, while in the bedroom, it was 1-2 windows. Thus, 47.2% of living rooms had 1 window, while 22.1% living rooms had 2 windows (Table 5). Also, 14.1% living rooms had 3 windows, with 16.6% having 4 windows. Also, 71.2% of bedrooms had 1 window, while 28.8% bedrooms had 2 windows.

The implication of this is that, the bulk of the houses in the estate had 1 bedroom which may be due to the size of family living in the houses.

Table 5: Number of Window in Living room and Bedroom

Number of Window	Living room		Bedroom	
	F (N)	(%)	F (N)	(%)
1	77	47.2	116	71.2
2	36	22.1	47	28.8
3	23	14.1	-----	-----
4	27	16.6	-----	-----
Total	**163**	**100.0**	**163**	**100.0**

Source: Authors' Fieldwork (2023)

However, three different window sizes were adopted in both the living room and bedroom. Analysis shows that 47.2% of the windows in the living room were 1.2x1.4m, while 38.7% windows in the living room were 1.2x1.5m; with 14.1% of windows in the living room having 1.2x1.8m (Table 6). However, 66.9% of bedroom windows were 1.2x1.4m, while 20.2% windows in the bedroom were 1.2x1.5m, with 12.9% of bedroom windows having 1.2x1.8m size. The implication is that, both living rooms and bedrooms of houses in the estate were not properly ventilated according to Chand (1976) and Ayinla (2011)'s recommendation that window openings should be between 30-50% of the exposed wall area.

Table 6: Window Size in Living room and Bedroom

Window Size	Living room		Bedroom	
	F (N)	(%)	F (N)	(%)
1.2x1.4m	77	47.2	109	66.9
1.2x1.5m	63	38.7	33	20.2
1.2x1.8m	23	14.1	21	12.9
Total	**163**	**100.0**	**163**	**100.0**

Source: Authors' Fieldwork (2023)

Further analysis as shown in Table 7 shows that 69.3% of the windows in the living room were single sided, while 30.7% were crossly placed (Table 7). In the bedroom, 73.6%were single sided, with 26.4% being crossly placed. Thus, the inference drawn is that windows are wrongly placed in the area thereby causing poor ventilation in both the living rooms and bedrooms.

Table 7: Placement of Windows in the Living room and Bedroom

Type of Wings	Living room		Bedroom	
	F (N)	(%)	F (N)	(%)
Single sided	113	69.3	120	73.6
Cross	50	30.7	43	26.4
Total	**163**	**100**	**163**	**100**

Source: Authors' Fieldwork (2023)

Also, analysis shows that poor ventilation exists in the area and it is due to wrong orientation of windows on external walls of both living rooms and bedrooms. Thus, more than two-fifths (47.2%) of the windows in the living room were facing northeast direction; 26.4% faced southeast, 14.1% were facing northwest, with 12.3% of living room windows facing southwest direction (Table 8). Similarly, more than two -fifths (46.0%) of bedroom windows faced northeast direction; 27.6% was facing southeast direction; 13.5% faced northwest direction, with 12.9% of bedroom windows facing southwest direction.

Table 8: Orientation of Windows in the Living room and Bedroom

Direction of Windows	Living room		Bedroom	
	F (N)	(%)	F (N)	(%)
Northeast/North	77	47.2	75	46.0
Southeast/East	43	26.4	45	27.6
Northwest/West	23	14.1	22	13.5
Southwest/South	20	12.3	21	12.9
Total	**163**	**100**	**163**	**100**

Source: Authors' Fieldwork (2023)

However, 15.3% of the houses assessed had their window sill level below 0.9m, while 38.7% had it to be exactly 0.9m from DPC (Table 9). The implication is that, the required air expected at the occupied zone would have been effective for ventilation comfort, but most of the windows were wrongly placed on the wall. Also, 46.0% of houses had window sill level above 0.9m and the implication is that the required air for effective ventilation within the occupied zone is not visible.

Table 9: Window Sill of Living room and Bedroom

Living room and Bedroom' sill height (m)	Frequency (N)	Percentage (%)
0.0 -0.8	25	15.3
0.9	63	38.7
0.9 above	75	46.0
Total	**163**	**100**

Source: Authors' Fieldwork (2023)

Table 10 shows the average indoor velocity of the assessed houses using the Giovanni empirical model in reference to the window type respectively. The average ventilation obtained in houses with louver, casement and projected window type were 0.33m/s, 0.40m/s and 0.35m/s respectively, while the least gotten in the living room was 0.21m/s with sliding window type. Considering both living room and bedroom space, the implication of those value is that according to Giovanni empirical model, none of the spaces satisfied ventilation comfort standard of 0.5-1.5m/s for warm humid climate.

Table 10: Average Indoor Air Velocity

Window type	Reference window area (m^2)		Reference wall area (m^2)		Window / wall area ratio (x)		Average indoor air velocity V_i (*m/s*)	
	LR	BR	LR	BR	LR	BR	LR	BR
Louver	1.62	1.44	8.10	7.20	0.20	0.20	0.33	0.33
Sliding	1.80	1.44	20.0	6.86	0.09	0.21	0.21	0.35
Casement	2.16	1.44	10.30	7.20	0.21	0.20	0.40	0.33
Projected	2.16	1.44	9.53	7.20	0.17	0.20	0.35	0.33

Source: Authors' Fieldwork (2023)

(iii)Residents' Satisfaction with Natural Ventilation

Similarly, analysis shows that more than seven-tenths of the residents were not satisfied with natural ventilation in the living room of the houses, while 73.6% of the residents were also not satisfied with natural ventilation of the bedroom of the houses at p=0.10. The implication of this is that natural ventilation is not adequate in the houses and thus, need additional mechanism for supplementation.

Residents' Satisfaction with Natural Ventilation in both Living room and Bedroom

Mass housing component	**Satisfied (%)**	**Dissatisfied (%)**	**Total (%)**
Living Room	28.8	71.2	100.0
Bedroom	26.4	73.6	100.0

P value =0.10 at 0.05 confidence level
Source: Authors' Fieldwork (2023)

Conclusion and Recommendations

This study has shown the mechanisms used for natural ventilation in Owode mass housing scheme, Ibadan, southwest, Nigeria. It has discussed building characteristics in the area as well as the mechanisms used for natural ventilation. As exemplified in this study, window was majorly used for achieving natural ventilation in the area and varies in number from one to four. The windows were placed either single sided or crossly placed and yet, majority of the residents were not satisfied with natural ventilation in both the living room and bedroom of the houses. It is thus recommended that more windows of appropriate sizes should be created in both the living room and bedroom of the houses so as to have enough air and make them conducive and this should be complemented with soft landscape elements.

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