NATURAL VENTILATION AND BODY HEAT COMFORT: AN EVALUATION OF RESIDENTS SATISFACTION IN OGBOMOSO, NIGERIA.

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ABSTRACT: *This study evaluates the variations in the level of natural ventilation in houses across the three main residential density zones of Ogbomoso. The study employs two approaches. First, it surveys the perception of residents with respect to the body heat comfort in their houses. Second, it examines the window opening sizes for compliance with floor areas considered desirable for effective natural ventilation in a warm humid climate like Nigeria. The main objective is to validate residents perception of body heat comfort through the assessment of window opening to floor areas ratio. The methodology employed is the multi-stage sampling procedure where houses are sampled from sampled streets, and a household head sampled from each house, such that the perception of residents and evaluation of window and floor areas ratio are both carried out on the same household and house, respectively. The result shows that residents' satisfaction as well as window to floor areas decreases with residential density zones.*

KEYWORDS: Natural Ventilation, Body Heat, Perception, Body Comfort, Satisfaction, Warm humid.

INTRODUCTION

One of the cardinal attributes of habitability in a house, and indeed any built form in the warm humid climate is efficient natural ventilation, or the ability to maintain a constant indoor temperature for residents living comfort, even in the face of fluctuations in outdoor temperature. The objective of the drive is to achieve natural ventilation and maintain body heat comfort in the house with little or no expenditure of energy, in Nigeria, a country in the Third world. This is a region in which Brew-Graves (1995) asserted that 30-60 percent of the populations live in grossly inadequate conditions of congested and poorly ventilated houses; or with poor urban housing conditions replete with overcrowding congestion and overstretch in urban facilities and services (Arayela, 2000; Diogu and Okwankwo, 2005). Energy is now considered a serious economic and sustainability issue in the built environment (Chapman 1974; Haseltine, 1975; Gatner and Smith 1989;). It is now regarded as a scarce resource in technology and specifically, Architecture where virtually, all building materials and the technology for their production are driven by one form of energy or the other (Atolagbe and Fadamiro 2005). Energy is indispensible in sourcing, manufacture, transportation and assemblage, and in cooling, warming and cleaning of built spaces. It is important in aiding users' goals and aspirations (Atolagbe, 2011). Indeed, energy may be regarded as the reason, and its control, the ultimate goal of Architecture. It is, today, a key design tool in the achievement of sustainable building the World over; and modern buildings are considered as being responsible for more than 40 percent of global energy consumption (Ohajuruka, 2013).

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The alternative to natural ventilation for indoor body heat comfort is the use of mechanical or electrical driven fans and air-conditioners, usually operated with cost-laden artificial energy. Thus, cooling by natural ventilation presents a welcome option not only for saving cost of energy and mechanical hardware, but also for its freedom from electricity hazards like electrocution, fire outbreak and fungal and bacterial health afflictions associated with air-conditioner condensates.

The aim of ventilation, either natural or mechanical is generally the same - to keep indoor temperature at the level of users' body comfort. The objective however, may and often differs with climatic differences. Whereas it is to keep the heat 'out' in warm humid tropical climate, it is to keep it 'in' in the cold temperate regions of the world.

In this study, the efficiency of natural ventilation in houses across Ogbomoso, a medium city in Nigeria, situated within a warm humid climate of Tropical Africa is examined in two mutually related stages. The first stage is through the perception of residents, the users of the houses whose expressed satisfaction with body heat comfort forms a major parameter for measuring the efficacy of the natural ventilation devices. The second is through evaluation of the devices consciously put in place by the designers of the houses to engender natural ventilation in the houses. One of these devices specifically evaluated here is the ratio of window openings to the floor areas of the spaces under study. Thus, the major research questions examined for answers include the followings: what are users perception of body heat comfort in the houses they live in? What are the ratios of window opening areas to the floor areas of the rooms under study? Does this ratio satisfy Chand (1976)'s minimum standard of window to floor areas required for adequate and effective ventilation in a warm humid climate region in which the city (Ogbomoso) is situated? This standard, by Chand (1976) Stipulates a range of 20-30% of window to floor areas for effective and adequate ventilation in the warm humid climate of the World. Do the window to floor ratio resulting from this survey validate or repudiate the perception of users in regards to body heat comfort in the houses? These are very salient among the questions the research exercise is set to find answers to.

RESEARCH METHOD AND PROCEDURES

In this study, the data was collected based on three easily recognisable residential areas, identifiable as the high, medium and low density zones. The high density, indigenous, inner city core is the precolonial settlement with compound-form houses of indigenous materials and techniques. The zone is characterized by small and few, far-apart windows. The medium density zone consists of the settlement of the colonial period, forming a ring around the inner high density residential zone. This zone consists of the roomy Brazilian houses which Olorunfemi (1995), referred to as 'barrack houses' with double banking central corridors Windows here are arranged at the outer walls of the double-row rooms.

The low density zone consists of the outer ring of post-independent, settlers, characterized by single, detached, nuclear family houses, with free plans and window arrangement. Thus, window sizes, arrangements and patterns are peculiar to zones and different across zones.

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Data were collected through a multi-stage sampling procedure from each zone. First, 50 percent of the streets were randomly sampled from each zone giving a total sample of 18, 15 and 14 streets in the high, medium and low residential density zones of the city, respectively. Next, a randomly systematic sampling procedure was adopted to pick every fifth house after the first house had been sampled randomly. This gave a total of 506, 377 and 359 houses from the high, medium and low density zones of the city respectively (Table 1). A household head was selected for interview in each house on the basis of first contact (purposive), for his/her perception on body heat satisfaction in the house. The scores were tabulated with frequency and percentage counts; and compared for compliance with the minimum standard values of (20-30%) window to floor areas ratio required for effective ventilation in warm, humid climate zone (Chand, 1976). An ANOVA test was carried out for significance of score distribution at 99 percent confidence level, using SPSS 10; (Table 1).

Table 1: Level of Users' Comfort Due to Heat Exchange in the Houses

Variable	Category	Residential Density Type								X^2 value	P value
		High		Medium		Low		Total			
		No	%	No	%	No	%	No	%		
Level of Human Comfort Due to Heat Exchange in the Houses	No Response	6	1.2	1	0.3	3	0.8	10	0.8	36.231	0.000
	Very Satisfactory	18	3.5	11	2.9	21	5.8	50	4.0		
	Satisfactory	206	40.6	211	56.0	193	53.3	610	48.9		
	Can not Decide	48	9.4	34	9.0	23	6.4	105	8.4		
	Unsatisfactory	200	39.4	105	27.9	112	30.9	417	33.4		
	Very Satisfactory	30	5.9	15	4.0	10	2.8	5	4.4		
	Total	508	100	377	100	362	100	1247	100		

Source: (Atolagbe, 2011)

A survey of window to floor areas was also done alongside the perception of users and both were recorded. However, two main (popular) types of window sizes were identified in the high density zone; and five each from the medium and low density zones of the city as shown in Table 2. The average window to floor area was calculated for each zone, based on the popular window arrangements and size of openings in each zone of the city as shown in Table 2.

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Table 2: Window, Floor and Exposed Wall Areas Ratios Across the City

Resident Zones	No. of Window Bays	Dimension Per Bay in height and width (mm^2)	Overall Window Opening Size (mm^2)	Floor Area length and Breadth (mm^2)	Percentage of window to Floor Area x/y X 100% (15 – 20%)
High	1	500h X 500w	250,000 mm^2 –	2400 X2000 – 4800,000 mm^2	5.21%
	2	600h X 600 w	360,000mm^2 –	2400 X 2400 – 5,760,000 mm^2	6.25%
Average					5.78%
Medium	1	1200hX1200w	1,200,000mm^2 –	3000X3000 – 9,000,000mm^2	13.33%
	2	1200hX1200w	1,440,000mm^2–	3600X3000 – 10,800,000mm^2	13.33%
	3	1200hX1500w	1,800,000mm^2–	3600X3600 – 12,960,000mm^2	13.80%
	4	1200hX1800w	2,160,000mm^2–	3600X4200 – 15,120,000mm^2	14.33%
	5	1200hX2000w	2,400,000mm^2–	3600X4200 – 15,120,000mm^2	15.87%
Average					14.11%
New	1	1200hX1200w	1,440,000mm^2–	3000X3600 – 12,960,000mm^2	11.11%
	2	1200hX1500w	1,800,000mm^2–	3600X3600 – 12,960,000mm^2	13.89%
	3	1200hX1800w	2,160,000mm^2–	3600X4200 – 15,120,000mm^2	14.28%
	4	1200hX2000w	2,400,000mm^2–	3600X4200 – 15,120,000mm^2	15.87%
	5	1200hX2400w	2,880,000mm^2–	3600X4200 – 15,120,000mm^2	19.04%
Average					12.68%

Source: (Atolagbe, 2013)

RESULTS AND DISCUSSIONS

The result showing users' satisfaction with body heat comfort across the residential zones of the city is shown in Table 2. A total of 44.1, 58.9 and 59.1 percents of residents were satisfied (either very satisfied or satisfied) with body heat comfort in the high, medium and low Residential density zones of the city, while 45.3, 31.9 and 33.7 percents were not satisfied (dissatisfied and very dissatisfied) in high, medium and low density residential zones, respectively. Thus user's satisfaction is highest in the low and least in the high, precolonial, indigenous settlement area of the city; that is satisfaction decreases with increasing population density. The difference with a calculated value of 36.231 is significant at 99 percent level of confidence.

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In regards to window opening to floor area ratio in the city, the highest average widow to floor area, percent (14.11%) was recorded in the medium density zone. This is followed with 12.68% in the low, density area, while the least, (5.78%), was recorded in the pre-colonial, indigenous settlement area of the city.

These values are more than the minimum window to floor area of 4% recommended for effective ventilation in the National Building Code (2006) for buildings in Nigeria. They are however below the 20-30 percent (Chand 1976), which forms the target for comparison in this study.

The higher satisfaction level of residents (59.1%), with body heat comfort in the low compared to the medium density area of the city may appear to contradict, or at least disagree with its lower percentage of window to floor area (12.68%) compared to the medium (14.11%). An explanation for this could be drawn from the housing environment in the two zones. The housing environments in the low density area are more friendly. There are more interstitial and air spaces between the houses; more soft elements of landscape like trees, flowers that condition the air for better natural ventilation in the zone. Besides, the morphology of houses in this zone allows most windows to be placed on adjacent, even opposite walls for cross ventilation. In contrast, houses in the medium density area are closer together, there are no, (at best very scanty), open spaces to allow for proper ventilation. In addition, the plan forms prevalent in the medium density zone are predominantly face-me-l-face-you rooms banking a central hall. This plan arrangement allows fenestration along outer walls of the room only; thereby foreclosing possibility of cross ventilation, as shown in Table 2.

Whereas about 50% of the windows in the low density area are located on opposite walls, a situation that maximizes natural ventilation through smooth and unhindered rate of air flow across rooms, such window arrangements constitute only 22 and one percents in the medium and high density areas of the city, respectively. Conversely, over 57% of the houses in the high density area have windows which are located on one side of the room; resulting in poor natural ventilation, higher room heat-trap and poor body heat comfort. In comparison, only 16.4 and 2.8 percents of the windows are on one side of the room in the medium and the low density residential areas of the city indicating higher, better arrangement for effective natural ventilation, increasing with lower density residential areas in the city, (Table 2).

Thus, from both users perception and optimal window arrangement, natural ventilation, is higher with lower density residential zones of the city. The seeming aberration is with higher window to floor area ratio in the medium than low residential zone; which can be explained off with the differences in room sizes and occupancy in both zones.

Though the windows are bigger in the low density zone, the rooms are also bigger denoting larger floor areas in this zone. Conversely, the windows are smaller on the average in the medium density zone, but the rooms are much smaller; giving a higher window to floor area in the medium. These higher window to floor area ratios advantages are however greatly offset by the poor arrangement of windows (along one side of the building) in the medium residential density zone.

Room sizes in the medium residential city zones are smaller while average room occupancy is higher than those in the low density residential zone. There are more people living per

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square metre of room space in this zone than in low density houses whose rooms are bigger and occupants fewer. But where rooms are overcrowded, more people contend with less volume of air to cool off per period of time, than bigger rooms; with fewer people, even when the flow rate, or velocity of air is the same in both. Thus efficiency of natural ventilation is higher in houses in the low than medium density areas even under normal conditions of air movement and window arrangement.

The result for both users' perception (of body heat comfort) and window opening to floor areas ratio for the high density zone calls for curious attention in this study! In the former about the same proportion of users express satisfaction (very satisfied and satisfied) and dissatisfied (dissatisfied and very dissatisfied), at 44.1% and 45.3%, respectively

(Table1). There is a much higher relative satisfaction of user's with body heat here, where the average window opening to floor areas is only 5.7% as against 14.11 and 12.68 percents in the medium and high density zones. This is because windows in the higher residential zone are disproportionately smaller still than in the medium residential density zone. This high relative body comfort may be due to the use of earth or mud wall for the majority of houses (59.1%) in this zone, compared to 5.6 and 5.0 percents in the medium and low density zones (Table 3). By virtue of better heat behavior of earth/mud wall: poor heat transfer and higher heat gradient, a more stable indoor room temperature and consequently better heat comfort is maintained in earth houses. Conversely, sandcrete block that constitutes 76.9 and 69.5 percents of wall materials in the medium and low density areas have poor heat behavior; allowing higher rate of heat conduction and thus transfer from the hot outside, to the indoor spaces.

Some other factor that contributes to relatively better natural ventilation in the high residential zone is nature of the ceiling. Table 4 shows that about 40% of the houses in this zone has no ceiling at all (22%) or has mat, bamboo or asana/grass stocks (17.32). The latter provides a high insulative material, disallowing heat from conducting through the metal sheet down to the indoor space; while the former dissipates heat in hot air through the roof eave (between metal roof cover and the wall plate) by stack effect. The latter is a suctioning process by which stale, used, but lighter air rises up the ceiling, where it mixes with hot air under the roof and streams out through the eave.

The net results of these added to the effect of the smaller size and fewer windows, in the high residential zone explain the paradox of small windows and relatively effective natural ventilation in Yoruba indigenous mud houses.

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Table 3: Spatial Dimension of Wall Materials in Ogbomoso

Variable	Category	Residential Density Type								X^2 value	P value >99%
		High		Medium		Low		Total			
		No	%	No	%	No	%	No	%		
Wall material	No Response	4	0.8	7	1.9	4	1.1	15	1.2	121.025	0.000
	Burnt claybocks	1	0.2	29	7.7	44	12.2	74	5.9		
	Sand cement block	122	24.0	290	76.9	251	69.5	663	53.2		
	Mal/laterite bricks	80	15.7	30	80	40	11.1	150	12.0		
	Coursed mud wall	300	59.1	21	5.6	18	5.0	339	27.2		
	Rough wood slabs used metal coatons	1	0.2	0	0	4	1.1	5	0.4		
	Total	**508**	**100**	**377**	**100**	**361**	**100**	**1246**	**100**		

Source: (Atolagbe, 2013)

Table 4: Ceiling Materials across the City

Variable	Category	Residential Density Type								X^2 value	P value
		High		Medium		Low		Total			
		No	%	No	%	No	%	No	%		
Ceiling material	No Response	26	5.1	12	3.2	3	0.8	41	3.3	731.031	0.000
	Plaster of Paris (POP)	3	0.6	13	3.4	88	24.2	104	8.3		
	Wood venner/coetot ex	11	2.2	42	11.1	89	24.5	142	11.4		
	Asbestos cement products	268	52.8	274	72.7	179	49.3	721	57.8		
	Mat/bamboo/ Asana	88	17.3	16	4.2	2	0.6	106	8.5		
	No ceiling at all	112	22.0	20	5.3	2	0.6	134	10.7		
	Total	508	100	377	100	363	100	1248	100		

Source: (Atolagbe, 2013)

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CONCLUSIONS AND RECOMMENDATIONS

Window size, especially its location in respect to floor area and orientation of the building determines the efficiency of air movement in a house. The latter also determines the comfort of users in regards to indoor heat or temperature. However, differences occur with variations in the room occupancy of a set of rooms with same sizes of window to floor areas; when the rate of flow of fresh air cannot meet the cooling needs of the occupants. Thus, in spite of the higher ratio of window opening to floor areas in the medium over the low residential density zones of the city, users satisfaction with body heat comfort is higher in the low residential zone where average room occupancy is lower than in the higher zones of the city. The nature of housing environment may also aid or detract from effectiveness of natural ventilation. Thus, the presence of more air spaces, elements of soft landscape-water, flowers, trees, etc, adds to better natural ventilation. These attributes of the houses in the low residential zone of the city, together with optimal window arrangement seem to have more than compensated for the smaller window to floor area ratio in houses in this zone.

Generally however, natural ventilation is poor, with most houses having window to floor area ratio well below the 20-30% required for adequate natural ventilation in the warm humid zone Nigerian climate; thus confirming the assertion in the literature that 30 to 60 percent of the populations of the Third World live in grossly inadequate conditions of congested and poorly ventilated urban houses (Brew-Graves, 1995; Arayela, 2000; Diogu and Okonkwo, 2005). The Pre-colonial and colonial settlers in the city in the core or high medium density zones are worse heat, falling dismally below the minimum standard of opening to floor areas. The houses are also very closely located in this zone, precluding the natural contribution of open spaces and landscape elements to natural ventilation. In the low density area where these nature elements appear to aid ventilation, it is also partly because a remarkable number of the plots have not been developed. The open spaces, flora and vegetation offered by these plots will disappear as more develop their plots. These, however, can not have much negative effect on natural ventilation in this zone. This is because most housing slots in this zone have large undeveloped land and vegetation areas around them. There is, therefore, the need to address natural ventilation from planning and designing policy perspectives.

The houses in the present settlements in the high and medium density zones of the city were developed at the whims and caprices of the settlers in the pre-independent Nigeria period when there were no development control agencies. In recent times, more residents of these zones have been relocating to the newer suburbs - the low density outer ring of the city. A two-prong of design and planning control policy should be put in place. First, no new development of building should be approved in the high and medium density zones, without adequate consideration for ample airspaces.

In the low residential zone, an aggressive building approval policy should not only be put in place, but pursued with vigour; and adequate specifications should be made, not exceeding 60% of the plot that can be built. In addition, two to four tree-plants and three to six shrubs should accompany the building development proposal in a standard plot of land (15x30) m^2; or same proportion for multiples of a plot.

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In addition hard pavements should not exceed 50 percent of the 40 percent open spaces around the houses. The rest 50% or 20% of the unbuilt part of the plot should be left and kept green – with flora.

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