Comparative Analysis of the Thermal Performance of Selected Public School Classroom Buildings in Lagos, Nigeria

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ABSTRACT: Limited research has been carried out on school buildings in Africa, especially for children below the age of 11. The aim of this research was to assess the thermal performance of the building envelopes of selected public school classrooms in Lagos Metropolis, in order to have an assessment of the impact of thermal performance (measurement of the environmental factors) on pupils' comfort. A two stage method of sampling was used; a purposive method to select 5 samples from each of the 6 educational districts in Lagos and then random selection of schools. Questionnaires were administered to 5 pupils per school. Subjective and objective measurements were carried out according to class II field experiment method and in consonance with ASHRAE's (American Society of Heating, Refrigerating and Air-Conditioning, Engineers) standards. Results showed that classrooms on the mainland had a significantly higher performance than those on the Island. Recommendations were made for future provisions of classroom designs to be suited to the microclimate of their locations and tailored towards enhancement of activities at the hottest periods of the day and year, and no single design template should be adopted for use on various sites.
KEYWORDS: Thermal Performance, Building Envelope, Thermal Comfort, Public Primary Schools, Lagos Metropolis.

1. Introduction

Buildings, the environment and related facilities produce more carbon dioxide (CO_2), generate more pollution, consume more energy, and use up more natural resources than any other sector. They are, therefore, at the crux of discussions related to energy efficiency, conservation and sustainability as a whole. In historical times, buildings were constructed with readily available materials and built for comfort and protection from the unfavorable weather. Therefore, materials used were sourced locally from their environs, and required little or no energy to construct them. With the advent of technology, the world became a global village and the boundaries of communication were broken. People can now live, interact, work and relate with the world at any given location. Building designs became more diverse as building styles were adopted from across nations irrespective of the climate in which they were located. This resulted in higher energy consumption in order to achieve thermal comfort. In the light of the global energy crisis, the need for buildings to become more passive, and use less of active energy became more evident

Building performance is the totality of building's operation and it is measured in three aspects; the environmental, energy and thermal. A total balance of all three aspects will provide a solution that is in harmony with its environment, offering comfort to its users while ensuring savings in energy and cost. The thermal aspect of performance is the ability of a building to offer thermal comfort to its occupants. In the quest for thermal comfort, various means have been adopted with the inclusion of the use of a proper architectural design, and the selection of an appropriate building envelope and components. Teli (2013, 301-316) also said that the use of eco-friendly, low thermal conductivity materials for living and work spaces, both at design and construction stages will address the problems of heat stresses due to climate change.

In the tropics, people are more prone to episodes of heat discomfort and heat stresses – adults and even children are, likewise, affected (Aynsley 1996). In Nigeria, specifically, the epileptic supply of power from the grid has necessitated the constant use of alternative power supply (the generator, inverter system or the solar panel) to achieve thermal comfort in many homes. Yet, a sustainable approach to development remains a 'buzz word' in construction, and also, remains cosmetic in its approach in the provision of buildings. Such are the current issues evident in the nation Nigeria.

Presently, buildings in Nigeria are being constructed without much consideration for the impact on occupant's health, productivity and comfort, (Adebamowo 2007); 'This is of great importance. Buildings often have poor indoor climate which affects comfort, health and efficiency. These problems are found in dwellings as well as work

spaces. The indoor climate has to be put in perspective in public buildings, such as hospitals, and schools'. This is the crux of the matter.

The focus of this research is on government-owned schools because they serve a greater percentage of the populace; they have standardized systems, curriculum and structure which will enable easy comparison. Class II Field experiment, which involves the measurement of both objective and subjective variables, protocols for thermal comfort consistent with ISO 7726 and ASHRAE standard 55-2010 was adopted for the research methodology, (Ogbonna & Harris 2008, 1-11).

The aim of this study is to assess the building envelopes and thermal performances of public primary school classrooms in Lagos Metropolis to determine their suitability towards comfortable task performance. The need for climate sensitive approaches and environmentally responsible construction of school facilities is not far-fetched. The level of education in Nigeria is dwindling (Odia et al 2005, 85-86). Standard approaches should be resorted to in the provision of conducive and comfortable classrooms in Lagos Metropolis and in Nigeria at large.

2. Literature Review

Lagos is one of the fastest growing cities in the world, at 77 persons per hour, (United Nations, 2014). It is bounded by the Atlantic Ocean on the South, Ogun state on the Northern and Eastern boundaries, and republic of Benin on the West. It is located on latitude of 6°22¹ N and 6°52¹ N as well as 2°42¹E and 3°42¹E. Lagos comprises of about 83% landmass and 17% Lagoons and waterways.

It is characterized by warm seasons for most of the year within June and September until October, and the dry season in Middle July till August. Average mean temperature ranges between 26-28°C, with high temperature at 31°C, especially in February and March. Its peak is in January and the lowest measurement is 21°C. Due to climate changes, values may be significantly higher. Over 60% of annual rainfall measured in the first half of the wet season. No month is completely without rainfall measuring as much as 25.4mm even in the dry season. Humidity levels are relatively at 75% especially in coastal regions of Lagos; this ranges from 90% at peak periods and 56% at low periods.

Lagos Metropolis is divided into sixteen Local Government Areas namely; Lagos Mainland, Surulere, Ikeja, Amuwo-Odofin, Kosofe, Ojo, Oshodi-isolo, Somolu, Mushin, Eti-Osa, Agege, Ifelodun, Alimosho, Epe, Ifako-Ijaye, Ibeju-Lekki, Lagos Island, Apapa . Lagos and its boundaries are shown in Figure 1.
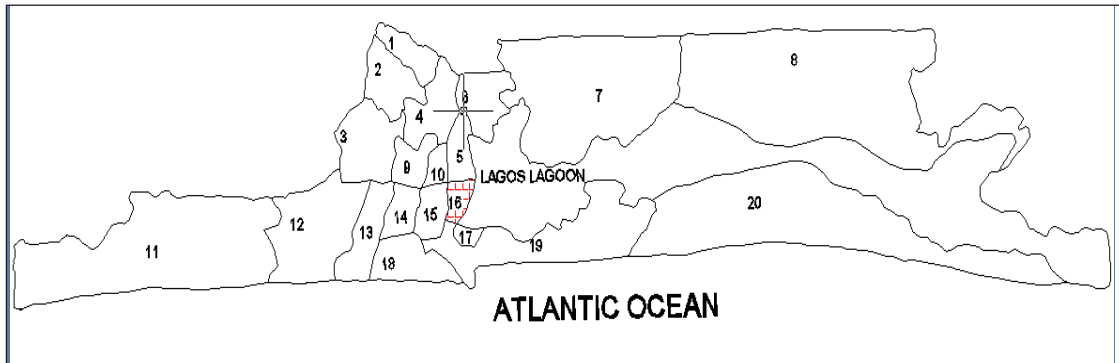
I *Figure 1. Map of Lagos showing the Local Government Areas*

LEGEND

1-Agege	5-.Shomolu	9-Oshodi- Isolo	13-Amuwo Odofin	17-LagosIsland
2-Ifako- Ijaye	6-Koshofe	10-Mushin	14-Ajeromi Ifelodun	18-Apapa
3-Alimosho	7-Ikorodu	11-Badagry	15- Surulere	19-Eti Osa
4-Ikeja	8-Epe	12- Ojo	16-Lagos Mainland	20-Ibeju-Lekki

Excluding 7, 8, 11, 2

2.1. Climate Characteristics Of The Study Area

The climate of an area impacts on the indoor thermal quality of the space; this depends on the form, design, structure characteristics and constituent of the building fabric. Optimal indoor environments in a building are basically a function of its form, the services it provides and the climate in which it is placed (Roaf, Fuentes & Thomas 2002, 140-148; Rijal, Hom, Humphreys et al. 2014). A study of the prevailing climate in the study area is therefore pertinent to this research.

The city of Lagos has a tropical climate. Specifically, it has been classified as warm and humid. The warm periods are more than the cold periods in Lagos. The Köppen-Geiger climate classification is 'Aw'. The temperature is at an average of 27.0 °C, with the highest over 30^0C, occurring in December to February. The average annual rainfall is 1693 mm (Climate-data.org). Humidity levels are high, especially at coastlines and in highest period of rainfall in June. The hot discomfort persists for about eleven months in the year, hence the need for adequate ventilation to achieve thermal comfort. The least yearly amount of rainfall occurs in the month of December and January. The

average measured value in these months is 21 mm. The greatest amount of precipitation occurs in June, with an average of 300 mm in a year a total of about 1506mm of rainfall is experienced. The temperatures are highest on average in March (warmest month-very hot), at about 28.5 °C. The lowest average temperatures in the year occurs in August (coolest month, though still warm), when it is around 25.1 °C. Average monthly temperatures have a variation of 3.45 °C (6.2°F) which is an extremely low range. There is a variation of diurnal average temperatures of 8 °C (14.5 °F).

2.2 Thermal Performance of School Building Envelopes

Climate, building characteristics and materials, indoor occupancy and equipment, and ventilation are significant factors in the determination of the thermal performance of the building structure and the corresponding indoor climate of its interior spaces.
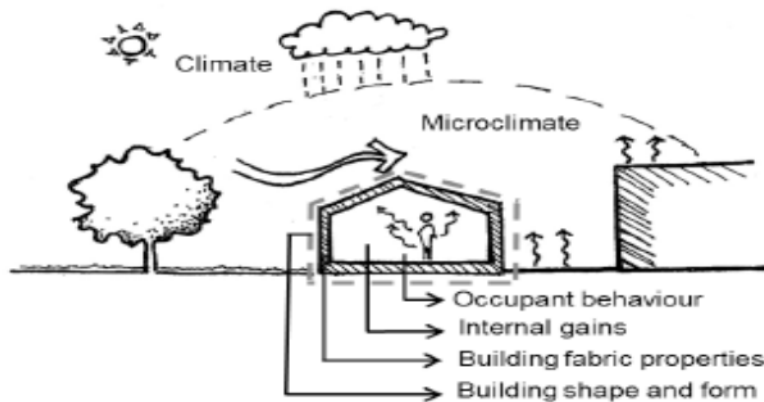

Figure 2: Parameters for Heat Gain or Loss in Buildings
Source: Teli, Jentsch et al (2013)

However the scope of this paper is the performance of the building envelopes alone the building's usage data (Internal heat gain, occupant's behavior) was not taken into consideration. However, the scope of this paper is the performance of building envelopes of public primary school classrooms, the building's usage data (Internal heat gain, occupant's behavior) was not taken into consideration.

There are basically two thermal properties of building materials that determines their effect on the thermal performance of the envelope and their effect on heat flow: their heat capacity and their thermal resistance (R-value).

These thermal properties depend on the thickness of the layers the material was composed of and their properties. The basic properties of building elements are specific heat, conductivity and density. Furthermore, the surface of these building elements absorbs solar rays striking it and also reflects some of it. Glazed materials transmit part of this striking radiation. So the properties of building materials in relation to radiation are: absorptivity, transmittance, emissivity and reflectivity. The values used in this research are seen in Table 1.

Table 1: Values of Properties of Various Building Materials

Table 1: Average Emissivities, Absorptivities and Reflectivities for Some Surfaces Common to Building

SURFACES	EMMISSIVITIES	ABSORPTIVITES	REFLECTIVITIES
Aluminum, Bright	0.05	0.02	0.08
Asbestos cement, new	0.95	0.60	0.04
Asbestos cement, aged	0.95	0.75	0.25
Asphalt pavement	0.95	0.90	0.10
Brass and Cooper, dull	0.20	0.60	0.40
Brass and Cooper polished	0.02	0.30	0.70
Brick, light buff	0.90	0.60	0.40
Brick, red rough	0.90	0.70	0.30
Cement, white Portland	0.90	0.40	0.60
Concrete, uncoloured	0.90	0.65	0.35
Glass	0.90	-	-
Marble white	0.95	0.45	0.55
Plant aluminum	0.55	0.50	0.50
Paint, white	0.90	0.30	0.70
Paint, brown red, green	0.90	0.70	0.30
Paint black	0.90	0.90	0.10
Paper white	0.90	0.30	0.70
Slate, dark	0.90	0.90	0.10
Steel, galvanized, new	0.25	0.55	0.45
Tiles, red clay	0.90	0.70	0.30
Tiles, black concrete	0.90	0.90	0.10
Tiles, uncoloured concrete	0.90	0.65	0.35

2.3 Calculations of Thermal Performance

In order to determine the value of the thermal performance of a building envelope, the estimation of the cooling loads is required. A building's thermal performance can also be accessed via statistical calculations and by the measurements of the environmental

variables. This survey employed the use of measurements of the environmental variables.

2.4 Characteristics Of Primary School Building Envelopes

Urban growth has resulted in high demand of public facilities. Educational facilities in urban areas are overstretched to meet the increasing number of school aged pupils. The design and construction of educational facilities are usually in modules, to facilitate easy repetition, economy of space and speed of construction (Wong & Khoo 2003, 337-351).

Spiegeller (2000) standards for primary school classroom layouts in Bhatan, Asia, cuts across, size, ages, proportions, ratio of heights or wall placements to ensure effective teaching and learning in primary schools. The average standing height measurement of each pupil is 132 cm. Distances from the blackboards is 2.00m, and spaces between rows are 0.95m. These standards come in dimensions for all class levels and for all range of activities carried out in pre-primary and primary school levels. The standard classroom size for primaries 1-3 is 40 pupils per class, with $1.00m^2$ per student. The standard class size for primary is thus 6.20x5.75m. The furniture type is squatting desks to suit the height of the pupils. The indoor and outdoor activities are closely related; therefore, primary school classrooms are advised to be situated on the ground level.

School design standards in low and middle income countries has it basis in international school design standards such as UNESCO standards (Spiegeller, 2000) but over the years these standards have ceased to serve the teeming population of pupils being enrolled. School building envelopes in Lagos presently vary in typology with respect to size, level, and location. Basic sizes of public school classrooms in Lagos are 6 x 6m, or about $40m^2$ (Uduku 2015, 56-64). A block of classrooms consists of about 4 or 6 classrooms in one row, measuring a total length of 36-40 m in length per block. The spacing from the blackboard or aisles of classrooms was varied. In Lagos, there are four basic shapes of school building envelopes in existence.

- *Types of School Building Envelopes In Lagos*

In Lagos are stratified based on the existing forms or layout, material specifications of the elements or components - walls, roofs, floors and windows, and structural type; bungalow, one story or two story buildings.

The double loaded corridors offer the advantage of economy of space and compactness however they require more ventilation and illumination, especially in internal spaces. Sen (2011) stated that classrooms should be designed as single banked layouts rather than double loaded layouts, and oriented in the direction of the prevailing wind. However, for urban cities with rapid growth such as Lagos, this is a rather a shortcoming.

Previously, classroom structures in the late 80's were constructed as dwarf-walled buildings with roofs suspended on wooden or iron pillars. These types of structures allowed for direct exposure to unfavorable elements like driving rain, strong winds, sandstorms and direct glare from the sun. These types of structures are being replaced with fully built-up structures presently. Classroom blocks in Lagos are stratified into bungalow type, low-rise or medium structures which could be one or two story buildings. Primary schools are usually situated on the ground floor of multistory structures, except where there are space constraints on the site. Building materials of schools in Lagos range from facing or hollow bricks, sand-crete hollow cement blocks, precast elements, ply-wood, aluminium and asbestos for roofing sheets, glazed plywood or galvanized iron sheet windows.

The building elements of public primary schools are summarized in Table 2:

Table 2: Building Elements of Public Primary Schools in Lagos

	Roof	Fenestrations	Wall	Floor
Materials	Asbestos	Concrete screen walls	Hollow cement block walls	Cement screed
	Concrete roofs	Grilled metal	Hollow clay bricks	Terrazzo flooring
	Long span Aluminium roofs	Galvanized Sheet metal	Precast Concrete wall	Cement Floor Tiles
		Glass windows	Facing bricks	

2.5 Thermal Comfort

ASHRAE defines thermal comfort as the state of mind which expresses satisfaction with the thermal environment; this is the same definition promulgated by Fanger (1986). The human body is in constant relationship with its environment through an exchange of heat. The balance in this exchange is what predicts the level of thermal comfort experienced by the body, (Anand, et al, 2017).

- *Thermal Comfort Basic Concepts*

For a human body to be in thermal balance, Heat gain must be equal to heat loss.

HEAT   GAIN   =   HEAT   LOSS

The basic concept of thermal comfort is shown above. Heat is generated in the body during metabolism, in breaking down of food substances during digestion. This heat is then lost to the environment through evaporation by sweating. This is known as the theory of adaptive thermal comfort. Adaptive thermal comfort states that the human body, given the time and opportunity, will carry out actions to achieve thermal comfort. This could be either voluntary, or involuntary. Voluntary actions include: taking bath, opening windows, taking cold drink, and loosening a knotted tie, while involuntary actions include: sneezing, shivering and sweating.

There are many factors related to comfort in classrooms i.e. physical, emotional, and psychological, all this impact favorably or otherwise on the performance of various tasks within them. Apter (1982, 1984, 2014) posited that the most influential factors on learning processes is the, temperature, noise and seat arrangement. Temperature plays a significant role in determining comfort while performing a task. Research on thermal quality, comfort and students' learning shows that 68 – 74°F and 20 -24°C is acceptable for learning (Earthman, 2000). Ventilation, which is the replacement of used up indoor air with fresh air from outdoors, is also an essential determinant of thermal comfort. It is often highlighted in most studies and measured as the concentration level of CO_2 dispensed in the air.

Ventilation can be enhanced in buildings through cross ventilation, stack effect, wind pressure and mechanical aids. Window positions, number, sizes, and external components also have an impact on the rate of ventilation within spaces. In warm humid settings, cross ventilation alone cannot suffice at high humidity levels, stack effect combined with mechanical or forced ventilation will aid quick evaporation of heat and sweat from the skin's surface. This is achieved when the ventilation flows cross the main activity spaces within the classroom. In measuring thermal comfort for humans, a climatic chamber will not be sufficient as vast amount of variability occurs in real life situations. Objective and subjective method of measurement will be more accurate and suitable. This is the basis on which ASHRAE standard II field survey is based. This was adopted for the research. The objective method required the use of instrumentation and recording of the four environmental variables earlier listed, (air temperature, relative humidity, mean radiant temperature, air velocity).Subjective

measurement involved the recording of the responses of the pupils (TSV- thermal sensation votes, PMV- predicted mean vote) through questionnaire administration, and detailed recording of their activity and clothing levels.

The different thermal comfort models from the literature under consideration are; the PMV, AMV, ASHRAE standard 55, ISO 7730. Although PMV has been established in colder climates and for buildings with HVAC, it can be used in warm climates with the introduction of the 'e' expectancy, factor. Researches are required to test if the PMV comfort equation could be applied to (young) children, as the relations between metabolic rate, skin temperature, sweat production and thermal sensation which are the basis of the PMV model might not be the same for children. (Teli et al. 2012). A summary of thermal comfort models in the existing literature is presented in Table 3.

Table 3: Various Thermal Comfort Models Sourced From the Literature

THEORIES	MODELS	AUTHOR / YEAR	SIMILARITIES /LIMITATIONS
Heat balance approach	PMV model (predicted mean vote)	Fanger (1970),	Derived from extensive climate chamber research; responses of over a thousand European and American subjects to the thermal conditions in a well-controlled environment were used to expand this equation into the PMV model. This equation and the PMV model are intended for use in the design of HVAC systems
	ISO standard 7730	Based on adaptive model	This takes into account physiological conditions as well as psychological. Which leads to certain variations in predictions and comfort calculations using the PMV. The ISSO 7730 states these viability intervals clearly, but when values fall outside of them, the results are likely to be unreliable
	ASHRAE Standard 55	Based on PMV model	Based on the PMV model.

	ADAPTIVE MODEL	Givoni B. (1976)	People, who live in naturally ventilated buildings, usually accept a wider range of temperatures and air speeds as normal. People have a natural tendency to adapt to changing conditions in their environment. This natural tendency is expressed in the Adaptive approach to thermal comfort.
	PMVe- expectancy factor	Fanger and Toftum (2002)	An improvement on the PMV model called the expectancy factor (e), usually 0.5- 1.0 and it is determined by location and frequency of warm periods. This improvement is to cover for discrepancies in the model with respect to non-air-conditioned spaces and warmer climates.
Comfort preference opposed to that of adults.	Humphreys Model	Humphreys and Nicol, 2007	This takes into consideration the variability of the PMV model with respect to children and their responses
Addendum to ASHRAE standards	ASHRAE Standard 55; 1992-2013		-1992-measuremnt protocols -PMV/PDD model and adaptive model included -Evaluating general thermal comfort in an occupied space with current POE practices.

3. Materials and Methods

The international standard for conducting thermal comfort field surveys, the class II field experiment which was stated by ASHRAE standard 55 was adopted in this study. It is based on the heat balance model of the human body, which predicts that thermal sensation is exclusively influenced by environmental factors (temperature, thermal radiation humidity and air speed), and personal factors (activity and clothing).

It involves both objective and subjective measurements. This resulted in the 'quasi experimental' design adopted in this study.

Discussions and training sessions were held with field assistants and interviews with school teachers to determine if the language and information required would be easily understood by the respondents prior to implementing the survey. Teachers of each classroom were also interviewed as well.

The field survey was conducted based on the class 2 field study method which requires both objective and subjective measurements. The field survey was carried out in mixed mode ventilated classrooms during dry season and onset of the rainy season from March till April and then, July till September 2016. Temperature and humidity readings for both indoor and outdoor were taken at intervals of 1hour (for 6 hourly readings) from the floor level at the center of the classrooms, at the seating and standing height of the pupils (corresponding with 0.1m, 0.6m, 1.1m). Pupils were to assume sitting or sedentary position for at least fifteen minutes, while the survey was being taken by the interviewer, (Adebamowo & Oginni 2016, 161-176). The orientation of the classroom and the external contexts of the building were noted. Clothing levels (a standard uniform) was 0.5clo corresponding with light summer clothing, according to ASHRAE clothing standards. Structured questionnaires recording the details of the buildings components were filled out. The surveying instruments required portable devices, as opposed to fixed instrumentation because of limited occupancy periods of schools (only day time use) and security reasons.

The questionnaire was adopted from Humphreys and Hancock (2007, 867-874) research carried out on primary school pupils using simple worded questions and emoticons (cartoons) to convey emotions or sensations. This was also based on the PMV's 7-point scale ranging from +3 to 0 and -3. 0 was for neutral temperature, +3 for hot and -3 for cold. The questionnaire was tested for the appropriateness of the language used in the questionnaire and a check was carried out also using older pupils within the same school locations as well as their teachers. A preparatory training was carried out for two weeks with the skilled field examiners, prior to the commencement of the field survey.

The population of study, 30, was drawn from each of the 6 educational districts (5 schools each) from each LGA in Lagos Metropolis; Oshodi, Sabo, Maryland, Agboju-Lagos, Victoria Island, and Agege. For the scope of this study, the subjects were mainly pupils of the ages 6-11, that is, those of primary level. The teachers of each unit were also interviewed to ascertain the validity of the survey tests carried out. The sampling frame was the six educational districts in Lagos shown in Figure 3.
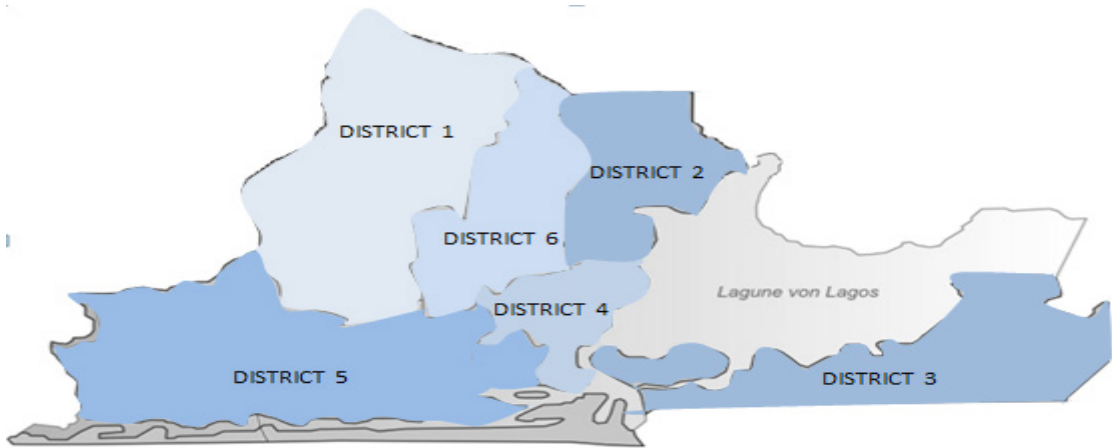
Figure 3: Map of Lagos showing the six educational districts in Lagos

Portable measuring instruments for Relative humidity, air temperature and air velocity meters were used such as the LM 8000.

Figure 4: LM 8000 Instrument Measuring Humidity, Air Velocity and Temperature

4. Analysis and Results

Below in Table 4 are the data from Pearson correlations test carried out on the samples.

Table 4: Statistical Analysis of Samples

		Paired Differences					Sig. (2-tailed)
		Mean Deviation	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
					Lower	Upper	
Pair 1	Alimosho LGA - Eti-Osa LGA	-3.6827500	3.1800940	1.0056340	-5.9576522	-1.4078478	.005
Pair 2	Alimosho LGA - Ikorodu LGA	.6711786	2.7185516	.8596815	-1.2735561	2.6159133	.455
Pair 3	Alimosho LGA - Surulere LGA	1.0976250	4.2567028	1.3460876	-1.9474368	4.1426868	.436
Pair 4	Alimosho LGA - Mushin-Oshodi-Isolo	-2.3682500	3.5387710	1.1190576	-4.8997343	.1632343	.063
Pair 5	Alimosho LGA - Kosofe LGA	-2.3682500	3.5387710	1.1190576	-4.8997343	.1632343	.063
Pair 6	Eti-Osa LGA - Ikorodu LGA	4.3539286	3.1209467	.9869300	2.1213378	6.5865193	.002
Pair 7	Eti-Osa LGA - Surulere LGA	4.7803750	2.9382049	.9291420	2.6785098	6.8822402	.001
Pair 8	Eti-Osa LGA - Mushin-Oshodi-Isolo	1.3145000	2.7692422	.8757113	-.6664965	3.2954965	.168
Pair 9	Eti-Osa LGA - Kosofe LGA	1.3145000	2.7692422	.8757113	-.6664965	3.2954965	.168
Pair 10	Ikorodu LGA - Surulere LGA	.4264464	2.9299501	.9265316	-1.6695136	2.5224065	.656
Pair 11	Ikorodu LGA - Mushin-Oshodi	-3.0394286	2.5276178	.7993029	-4.8475774	-1.2312797	.004
Pair 12	Ikorodu LGA - Kosofe LGA	-3.0394286	2.5276178	.7993029	-4.8475774	-1.2312797	.004
Pair 13	Surulere LGA - Mushin-Oshodi	-3.4658750	2.4728883	.7819959	-5.2348727	-1.6968773	.002
Pair 14	Surulere LGA - Kosofe LGA	-3.4658750	2.4728883	.7819959	-5.2348727	-1.6968773	.002

Table 5: Statistical Analysis

PAIRED T-Test of LGA In Lagos	P-VALUE	INFERENCE
Alimosho LGA - Eti-Osa LGA	.005**	There is a significant difference in the means
Alimosho LGA - Ikorodu LGA	.455	There is no significant difference in the means
Alimosho LGA - Surulere LGA	.436	There is no significant difference in the means
Alimosho LGA - Mushin-Oshodi-Isolo	.063	There is no significant difference in the means
Alimosho LGA - Kosofe LGA	.063	There is no significant difference in the means
Eti-Osa LGA - Ikorodu LGA	.002**	There is a significant difference in the means
Eti-Osa LGA - Surulere LGA	.001**	There is a significant difference in the means
Eti-Osa LGA - Mushin-Oshodi-Isolo	.168	There is no significant difference in the means
Eti-Osa LGA - Kosofe LGA	.168	There is no significant difference in the means
Ikorodu LGA - Surulere LGA	.656	There is no significant difference in the means
Ikorodu LGA - Mushin-Oshodi-Isolo	.004**	There is a significant difference in the means
Ikorodu LGA - Kosofe LGA	.004**	There is a significant difference in the means
Surulere LGA - Mushin-Oshodi-Isolo	.002**	There is a significant difference in the means
Surulere LGA - Kosofe LGA	.002**	There is a significant difference in the means

** Significant

The above Table 5 shows a paired sample T test of the mean radiant temperatures of six groups of local government areas in Lagos state, Nigeria. The ones that had significant difference in their means were denoted by a double asterisk. The following groups of LGAs are the ones with significant mean radiant temperatures:

Alimosho LGA - Eti-Osa LGA

Eti-Osa LGA - Ikorodu LGA

Eti-Osa LGA - Mushin-Oshodi-Isolo

Ikorodu LGA - Mushin-Oshodi-Isolo

Ikorodu LGA - Kosofe LGA

Eti-Osa LGA - Surulere LGA

Surulere LGA - Mushin-Oshodi-Isolo

Surulere LGA - Kosofe LGA

From the mean deviation shown above as the mean, it reveals that the Mainland classrooms have higher mean radiant temperatures compared to that of the Island classrooms and local governments situated by the Ocean. This is seen in the negative mean deviation shown in Table 4 above. It is also evident that some mainland LGA's have higher mean radiant temperatures than the others. From Table 5, it is seen that Surulere classroom's performance was significant compared to most LGA's on the Mainland. From Table 4, it is also evident that the paired LGA, whose absolute mean deviation is more than 3 shows a significant difference in their mean radiant temperature. Particularly, among the LGAs in the mainland, Surulere LGA's shows significant difference compared to other LGAs in Lagos mainland.

5. Conclusion and Recommendations

The main aim of this study was to assess the building envelopes and thermal performances of public primary school classrooms in Lagos state. The study was based on the data obtained from a triangulation of survey and experimental design. The field survey was carried out in mixed mode ventilated classrooms during dry season and onset of the rainy season between March till April and July till September 2016. The results ranged from both subjective and objective measurements.

The comfortable thermal sensation (acceptability) has been observed for the temperature range from 25 to 31°C from the dry to wet seasons. Most of the subjects who recorded cool thermal sensation and preferred a warmer climate in cold or wet seasons and those of the subjects who were 'slightly warm' and 'hot' preferred a cooler environment in the dry seasons. Also, it was discovered that the pupils' responses were "happy" irrespective of the value of the objective measurements taken. It can be concluded that the deviation in TPV to that of corresponding TSV especially

in the 'neutral or okay' zone is as result of children's inclination to be playful and happy regardless of the prevailing conditions. This is in line with Humphrey's (2007) research, where he stated that children probably do not relate discomfort with feelings of happiness or sadness. That is why irrespective of the discomforts, they still signified being happy. However, the effect of discomforts on their concentration and productivity is yet another issue of discourse.

The buildings' characteristics impacted on the values of thermal performance (temperature, humidity variables), which were the two most significant factors. These factors are mostly important for the warm-humid tropics of Lagos. When the air is dry, further evaporation of air through adequate ventilation will cool the surface of the skin and ensure comfort of occupants. But when humidity is high, as well as temperature, evaporation through ventilation alone is insufficient for comfort as the skin remains 'clammy' and 'damp' as a result of oversaturation of the air. Further is then required assistance through mechanical means.

Recommendations

The design of building envelopes should enhance activities taking place at uncomfortable periods of the day, midday, when the weather is hot, internal walls could be collapsed to open into outdoor patios or provide alternative means of adapting to such conditions. Material specifications are rarely considered in Nigeria - especially with considerations for indoor thermal comfort. Low albedo materials can be oriented away from the East West direction, shaded or insulated as the case may be. Roof forms or type also have a significant effect on thermal comfort. Deeper roofs with larger surface areas project heat inwards, especially without appropriate treatment or ceilings. If the building does not require a ceiling, deep verandas of about 1.5m will be necessary for cooler interior spaces.

Pitched roofs have better surface cooling compared to flat or lean-to roofs. Barrel roof types offer the best advantage of ventilated roof surfaces, as the resistance to wind pressure reduces over a curved surface and this encourages higher wind speeds on the roof top. The result is a cooler roof surface at the top of such buildings and cuts down the amount of heat that inadvertently would be transmitted through to the interior below. Therefore, higher roof pitches and barrel roofs are advised. Reflective colours and high albedo materials are also inclusive. The common use of metal windows in Lagos state classrooms should be prohibited. Their heavy metal frames and thick projector planes allow for heat infiltration indirectly inwards especially when windows

are un-shaded from the sun. They also cut down illumination once shut against driving rain on wet days. Fiber glass is preferable as window windowpanes in louvre systems, as they are good insulators, safe and durable. As louvre blades, they can be regulated to suit whatever weather condition or solar insolation angle is prevailing. This is consistent with the recommendations made by Elaiab (2014), who proposed using fibre glass as insulation of flat roofs.

This research recommends the use of computer simulation tools to explore options in the preconstruction stages. Decisions made on material and forms of school classrooms in the tropics should enhance an efficient thermal performance and subsequently, thermal comfort. Post Occupancy Evaluation of schools with respect to indoor environmental conditions should be carried out from time to time to provide necessary information for future construction as well as retrofits. Height of pupils' workstations should suggest window placements and stack effect alongside cross ventilation should be included to enhance adequate ventilation of spaces.

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