INTEGRATING INDOOR THERMAL COMFORT OPPORTUNITIES FROM TRADITIONAL BUILDING TYPES INTO THE DELIVERY AND MANAGEMENT OF SUSTAINABLE BUILT ENVIRONMENTS

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ABSTRACT

Amid the different contemporary strategies for the delivery and management of sustainable development in the African context, not much emphasis has been placed on seeking for the existence or otherwise, of thermal opportunities from the inherent building types of our forebears. This paper therefore, through case study design approach, reported the developmental trend of indoor thermal comfort opportunities of building types with the design and construction traits representing the historic eras of pre-colonial, colonial and contemporary in Okigwe, Nigeria. The primary data were got from field observations made for 366 days (1 November 2015 – 31 October 2016) on the indoor and outdoor temperature and relative humidity values using Tinytag Explorer 4.9 Germini data loggers and secondary data from the nearest Meteorological Station, Imo State International Cargo Airport, Owerri, Nigeria. The mean annual outdoor temperature and relative humidity values were 29.0^0C and 69.9% respectively. Analyses of the results using one-way ANOVA test for differences were statistically significant; indoor air temperature [F (2, 1095) = 77.56, p = 0.0001] and relative humidity [F (2, 1095) = 5.76, p = 0.0001]. Further interrogation using the Tukey's HSD (Honest Significant Difference) post-hoc comparison test amongst the building types revealed that indoor air temperature (27.83^0C) and relative humidity (71%) of pre-colonial building type were significantly different from those of colonial (28.43^0C and 67.39%) and contemporary building types (29.27^0C and 66.75%). The paper recommended that the valid traditional practices as expressed in the pre-colonial building types be re-integrated into the delivery and management of sustainable development in Nigeria. Thus, it concluded that opportunities abound in the indoor thermal comfort traceable to the traditional building (pre-colonial) types of our forebears as they performed thermally better than colonial and contemporary building types.

Keywords: Contemporary building, Indoor thermal comfort, Okigwe-Nigeria, Sustainable development and Traditional building

1. INTRODUCTION

Optimum comfort is necessary because a lot of health-related challenges and low productivity are traceable to poor design of buildings especially when it has been established that humankind spend prolonged time inside buildings performing activities (Koenigsberger, et al., 1973; Nematchoua, et al., 2014). Different climates, cultures and traditions similar to the diverse regions throughout the world are not gifted with all buildings materials either in type or in quantity; hence forms and types of shelter differ (Obinegbo, 2011). Each culture, tradition and regions developed her architecture based on the availability of these materials and its ability to use them within the domain of their knowledge competence. Mud (*known as 'aja ulo' in Igbo language of eastern Nigeria*), timber (*osisi*), bamboo (*achara*), palm midribs (*ogugu*), thatch (*akilika*) and rope (*udo*) were the principal materials used for building construction before the independence (pre-colonial) of Nigeria from the British colonialists (Nsude, 1987). During the era of the British colonialists, the building industry became influenced by their systems, materials and techniques. This was followed by hybridized building types that combined traits of traditional and foreign systems, materials and techniques (Adeyemi, 1987).

With the 1960 independence of Nigeria, the adoption and utilization of the systems, materials and techniques learnt from the colonialists reshaped the architecture of our forebears. Thus the beginning of contemporary architecture that promotes the use of electro-mechanical devices for comfort solutions. The invention of steel, glass, plywood and other materials gave more stimuli to the evolution of contemporary building types, however, compatibility with the climatic and socio-cultural milieu of the locale remains the albatross and search for comfort and well-being of the occupants persists (Adeyemi, 1987).

The global rise in average temperature as one of the consequences of climate change resulting in more energy requirements for space cooling as well as concern in developing energy-conscious buildings have put the architects and other environmental designers and planners to task on the continued reliance on imported mechanical and artificial systems, materials and techniques (Roaf, et al., 2009). While attaining the desired indoor thermal comfort levels, different systems, materials and techniques were manipulated by humankind as evidenced in the components and methods of construction of buildings in the pre-colonial, colonial and contemporary historic eras.

The adaptation of building forms and materials for fabric composition from pre-colonial, colonial and contemporary times were based on fashions and socio-economic and cultural status definitions. Amid the different contemporary strategies for the delivery and management of sustainable development in the African context, not much emphasis has been placed on seeking for the existence or otherwise, of thermal opportunities from the inherent building types of our forebears. Therefore, this paper through case study design approach, reported the developmental trend of indoor thermal comfort opportunities of building types with the design and construction traits representing the historic eras of pre-colonial, colonial and contemporary in Okigwe, Nigeria.

2. LITERATURE REVIEW

The global attainment of sustainable development in design and construction requires consideration of the needs of the present without compromising the ability of future generations to meet their own needs (El-Betar, 2017). Further, El-Betar (2017) stated that environmental friendliness, economic feasibility as well as healthiness and occupants’ comfort should be the hallmark of sustainability in the construction sector. Buildings as part of the construction sector account for nearly half of all energy consumption and raw materials use around the globe and equally responsible for a third of the total global greenhouse gas (GHG) emissions (Attmann, 2016; Alrashed, et al., 2017) The forms and materials of the building envelopes constitute the interface between external and internal environments and as such control the energy efficiency, indoor thermal conditions and functional performance of buildings. The building envelope is described as the climate moderator and also provides the first line of defense against the impact of the external climate on the indoor environment (Lee & Tiong, 2007).

Several strategies have been adopted by humankind to ensure acceptable thermal comfort, one of which is the use of varying forms and materials for the composition of the envelope of buildings. Others are seasonal and diurnal migrations from hot to humid areas or vice versa, or from one part of the space in the building to another in search of comfort. Equally evolved were systems of warming and/or cooling through heating, ventilation and air-conditioning (HVAC) and development of life-styles and energy-consciousness toward the built environment (Roaf, et al., 2009).

Givoni (1981) stated that whenever a beam of radiant heat energy strikes the surface of any solid body, it is either reflected away, absorbed or transmitted by the surface of that body. This demonstrates that building envelopes gain more heat during the day and conversely, loose heat during the nights. Heat is also, gained and lost through the building envelope as in the human body, thus rationalizing the significance of building envelopes and its composition in the discursive field of indoor thermal environment. However, heat is said to be transferred when there is a temperature difference between two bodies, probably between bodies of higher and lower temperatures.

The human body is very sensitive to temperature and for maintaining deep body temperature and thermal balance, the total heat gained must be equal to the total heat lost. The temperature of the human body and interior of buildings must be maintained within a narrow range to avoid discomfort, and within a somewhat wider range, to avoid danger from heat loss or cold stress. Properties of materials that constitute building envelope components are evaluated in terms of their absorptivity, conductivity and thermal capacity, as well as air-to-air transmittance (U-value), solar gain factor, time lag and admittance. Summarily, the physical built environment can also affect the thermal environment, thereby contributing to the control of the body temperature

American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) in ASHRAE (2004) defined thermal comfort as that condition of mind which expresses satisfaction with the thermal environment. Several studies such as: Koranteng et al., (2015) Cui et al., (2013) and Djongyang et al., (2010) identified four environmental factors of air temperature, relative humidity, mean radiant temperature, air velocity; and two personal factors of metabolic rate and clothing insulation as the factors that define thermal comfort and also established the indices for its measurement. However, air temperature was singled out as the main parameter affecting design since it determines the sensation of occupants within the spaces (Al horr, et al., 2016). Koenigsberger et al., (1973) emphasized that treatment and selection of materials for the building envelope influence its thermal behaviour and aid in the reduction of the heat load. Alhaddad et al., (2013) through a simulation study revealed that indigenous materials have significantly better thermal properties as compared to contemporary building materials in Sana'a, Yemen. In another related study at Kumasi, Ghana, by Koranteng et al., (2015) it was reported that materials differences do not significantly have any effect on indoor comfort but rather the orientation of the building. However, Croome (1991) and Al horr et al., (2016) opined that human activities and aspirations can only be optimized when indoor environmental conditions are comfortable.

The design challenge in warm-humid climate revolves around the mitigation of adverse effects of elevated temperatures and humidity. Despite global concerted efforts toward reduction of energy consumption for sustainable development, there is still paucity of studies on the thermal performance of building envelopes or fabrics spanning the pre-colonial, colonial and contemporary periods in Nigeria. Wahab (2015) noted that other aspects of thermal comfort studies carried out by Sharma and Ali in 1986; Ogunsote and Pruncal-Ogunsote in 2002; Ajibola in 2001 and Adunola in 2012 concentrated on thermal performance of residential buildings and its occupants' responses to thermal environment without looking at the influence of the envelope composition on the indoor environmental variables of air temperature and relative humidity.

Therefore, this paper investigated the indoor thermal comfort qualities of air temperature and relative humidity of residential buildings in Okigwe, Nigeria, spanning pre-colonial, colonial and contemporary historic eras, with a view to drawing lessons from their fabric composition for the advancement of sustainable development in design and construction. The specific study objectives were to determine the indoor air temperature and relative humidity values of the building types and it was hypothesized that no statistically significant differences existed between the indoor air temperature and relative humidity values of the building types.

3. RESEARCH METHODOLOGY

3.1 The Study Area

Okigwe, a semi-urban city in the warm-humid climate of Nigeria lies between Latitudes 5^0 30' and 5^0 57' North of the Equator and Longitudes 7^0 04' and 7^0 26' East of the Greenwich Meridian. It experiences dry and rainy (wet) seasons. The mean annual temperature value is 26.4^0C with 27.6^0C, 25.0^0C and 2.6^0C as maximum, minimum and range values respectively. The annual precipitation is over 2000mm. Relative humidity is high in the mornings and during rainy seasons ranging from 80% to 100% while in the afternoons and dry seasons, it falls between 60% and 80% respectively. Okigwe, experiences the conventional type of rainfall due to its proximity to the equatorial belt. Rainfall is heaviest during the months of June and July.

3.2 Research Design

This paper reports findings from a parent study on comparison of indoor thermal comfort conditions of traditional and contemporary buildings in the dry season at Okigwe, Nigeria. The parent study was done with the aim of establishing design criteria for thermally comfortable environment and the objectives examined thermal design characteristics and sensations of the occupants; it also determined indoor environmental variables of air temperature and relative humidity and also compared their thermal sensations and indoor air temperature and relative humidity values.

To gain an in-depth understanding of the phenomenon of indoor and outdoor air temperature, the case study research design approach was adopted. The primary data were collected on three purposively sampled existing residential buildings representing the fabric composition of pre-colonial, colonial and contemporary building types, whereas the secondary data were obtained from the nearest Meteorological Station, Imo State International Cargo Airport, Owerri, Nigeria.

From Table 1, the pre-colonial building type was a bungalow with mud walls, thatch roof and rammed earth floor with no ceiling cover. It is located between latitude 5^0 48’ 57” N and longitude 7^0 18’ 45” E. The colonial building type was a bungalow constructed with mud walls and roofed with corrugated iron metal sheets. It had partial ceiling cover internally and none externally except for the open entrance foyer area and floor finish was made of rammed earth. It lies between latitude 5^0 49’ 16” N and longitude 7^0 19’ 04” E. It had both the characteristics of pre-colonial (mud walls) and colonial (corrugated iron metals sheets). The contemporary building type was a bungalow made of sandcrete blocks as walling material, corrugated iron metal as roofing sheets and cement/sand screed as flooring material. It had asbestos ceiling sheets and located between latitude 5^0 44’ 48” N and longitude 7^0 11’ 36” E.

3.3 Data Collection

The indoor environmental variables of air temperature and relative humidity were monitored simultaneously on hourly basis for 366 days (1 November 2015 to 31 October 2016). Tinytag Explorer 4.9 Germini Data Loggers (air temperature range of -25^0C to $+85^0$C and relative humidity range of 0% to 100%) were mounted on a height of 1200mm above the finished floor level. Table 2 shows annual mean, minimum and maximum values and statistical summary of indoor air temperature (^{0}C) and relative humidity values of the pre-colonial, colonial and contemporary building types from Nov 2015 – Oct 2016.

Table 1: Envelope Characteristics of the Sampled Building Types

Type	Pre-Colonial Building type	Colonial Building type	Contemporary Building type
Nature	Bungalow	Bungalow	Bungalow
Roof	Thatch (akilika)	Iron metal sheets	Iron metal sheets
Wall	Mud (aja-ulo)	Mud (aja-ulo)	Sandcrete Blockwall sheets
Floor	Rammed earth	Rammed earth	Cement/Sand screed
Ceiling	No ceiling	Partially	Asbestos sheets
Latitude	5^{0} 48’ 57” N	5^{0} 49’ 16” N	5^{0} 44’ 48” N
Longitude	7^{0} 18’ 45” E	7^{0} 19’ 04” E	7^{0} 11’ 36” E
Photo	 	 	 

Source: Fieldwork (2016)

3.3.1 Data on indoor air temperature and relative humidity values

Table 2: Statistical Summary of Indoor and Outdoor Air Temperature (^{0}C) and Relative Humidity (%) of the sampled buildings types from Nov 2015 – Oct 2016

	Pre-Colonial Building Type	Colonial Building Type	Contemporary Building Type
Indoor Air Temperature			
Frequency	366		
Annual Mean Temp. (^{0}C)	27.83	28.43	29.47
Annual Min. Temp. (^{0}C)	24.60	25.18	25.44
Annual Max Temp. (^{0}C)	32.13	32.49	33.00
Standard Deviation	1.57	1.55	1.59
Indoor Relative Humidity			
Annual Mean RH (%)	70.89	67.39	66.75
Annual Min. RH (%)	19.76	19.26	19.77
Annual Max RH (%)	90.83	87.08	87.36
Standard Deviation	18.61	17.14	17.44
Outdoor Temperature			
Annual Mean Outdoor Temp. (^{0}C)	29.00		
Annual Mean Outdoor RH (%)	69.9		

Source: Fieldwork (2016) and Meteorological Station, Imo State International Cargo Airport (2016)

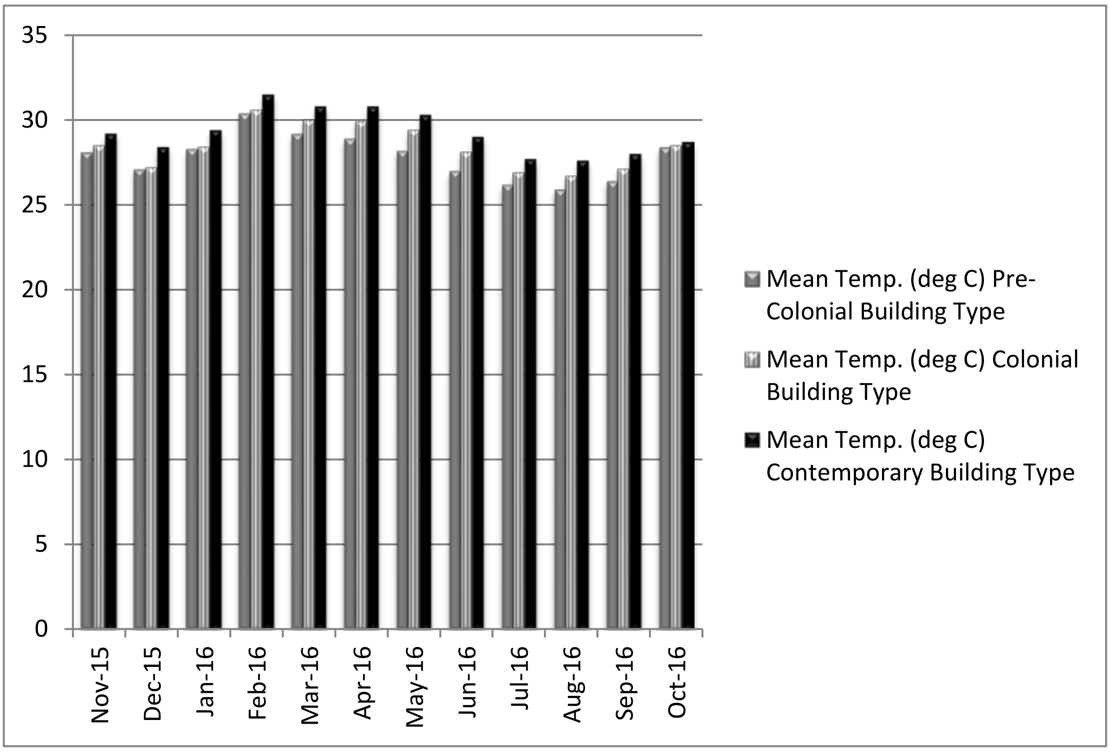

Figure 1: Comparison chart between the monthly mean indoor air temperature (^{0}C) values of the sampled building types from Nov 2015 – Oct 2016

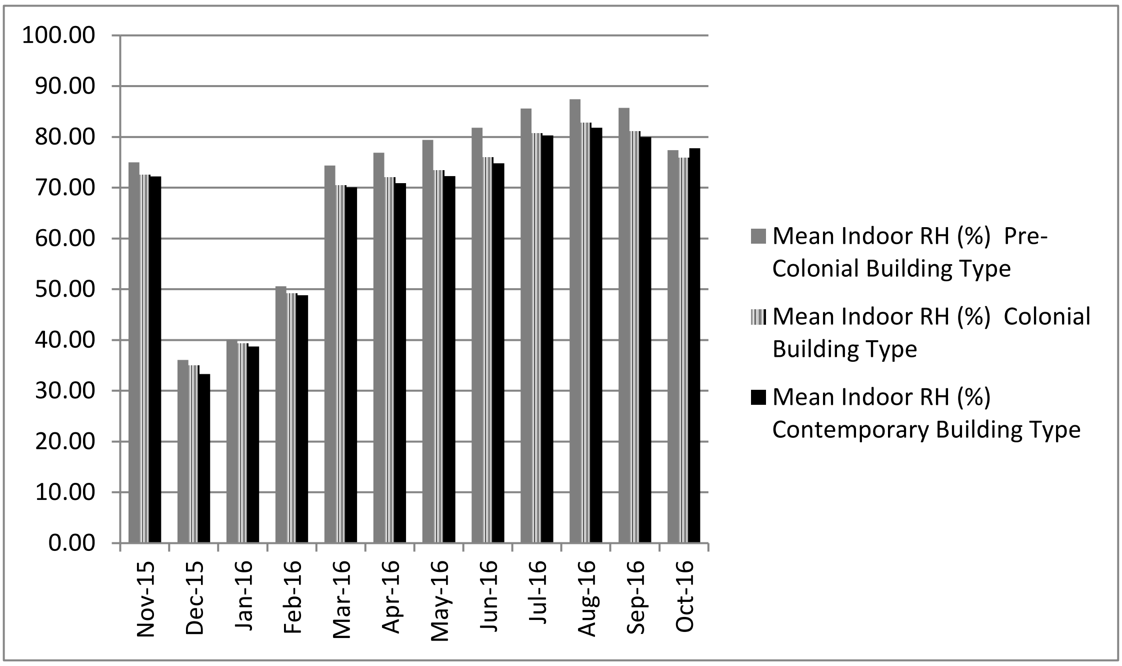

Figure 2: Comparison chart between the monthly mean indoor relative humidity (%) values of the sampled building types from Nov 2015 – Oct 2016

4. FINDINGS AND DISCUSSION

Table 2 shows that the mean and standard deviation of indoor air temperature values of pre-colonial building type were 27.83^{0}C, and 1.57^{0}C respectively, whereas 32.13^{0}C and 24.60^{0}C were recorded as maximum and minimum respectively. The colonial building type had M = 28.43^{0}C, and SD = 1.55^{0}C, with maximum and minimum indoor air temperature values as 32.49^{0}C and 25.18^{0}C. In the contemporary building type, M = 29.27^{0}C, and SD = 1.59^{0}C, and maximum and minimum indoor air temperature values as 33.00^{0}C and 24.44^{0}C. Further, the mean and standard deviation of indoor relative humidity for the pre-colonial building type were 71%, and 19% respectively. The maximum and minimum indoor relative humidity values of 91% and 20% were recorded respectively. The colonial building type had M = 67%, and SD = 17% with maximum and minimum indoor relative humidity values as 87% and 19% respectively. In the contemporary building type, M = 67%, and SD = 17%, maximum and minimum indoor relative humidity values were obtained as 87% and 20% respectively. The mean annual outdoor temperature and relative humidity values were 29.0^{0}C and 69.9% respectively.

Two null hypotheses were postulated on the non-existence of statistically significant differences between indoor air temperature and relative humidity values of the building types, and were tested at 95% confidence level. A one-way ANOVA test shown in Table 3 was conducted to compare the indoor thermal comfort conditions of the three building types: Pre-Colonial, colonial and contemporary, using their indoor air temperature values. The result showed that the overall F was significant [$F(2, 1095) = 77.56$, $p = 0.0001$]. Another ANOVA test shown in Table 4 was conducted to compare the indoor thermal comfort conditions of the three building types: Pre-Colonial, colonial and contemporary, using their indoor relative humidity values. The result also showed that the overall F was significant [$F(2, 1095) = 5.76$, $p = 0.0001$].

Tukey's HSD (Honest Significant Difference) post-hoc analyses were conducted given the statistically significant omnibus ANOVA F-tests as reported in Tables 3 and 4. The tests were conducted on all possible pair-wise comparisons. The null hypothesis for indoor air temperature was rejected because the absolute mean difference of the paired group was larger than the critical value calculated as 0.2264. The following pairs of groups were found to be significantly different: Pre-colonial building type (M = 27.83^{0}C, SD = 1.57^{0}C) with colonial building type (M = 28.43^{0}C, SD = 1.55^{0}C); pre-colonial building type (M = 27.83^{0}C, SD = 1.57^{0}C) with contemporary building type (M = 29.27^{0}C, SD = 1.59^{0}C) and colonial building type (M = 28.43^{0}C, SD = 1.55^{0}C) with contemporary building type (M = 29.27^{0}C, SD = 1.59^{0}C). However, the result shown in Table 5 indicates that a mean difference of 1.44^{0}C exists between pre-colonial and contemporary building types; 0.84^{0}C between colonial and contemporary building types and the least mean difference of 0.6^{0}C was determined for pre-colonial and colonial building types.

Table 3: ANOVA Test for Indoor Air Temperature (^{0}C) of the Building Types

	Source of Variation	**SS**	**df**	**MS**	**F**	**Sig**
Indoor Air Temperature of the Building types	Between Groups	382.60	2	191.30	77.56	0.0001
	Within Groups	2700.80	1095	2.47		
	Total	3083.40	1097			

Table 4: ANOVA Test for Indoor Relative Humidity RH (%) of the Building Types

Indoor RH	**Source of Variation**	**SS**	**df**	**MS**	**F**	**Sig**
	Between Groups	3621.62	2	1810.81	5.76	0.0001
	Within Groups	344524.34	1095	314.63		
	Total	348145.96	1097			

Table 5: Post Hoc Comparison for Indoor Air Temperature (^{0}C) of the Building Types

Buildings/ Mean (^{0}C)	**Group (^{0}C)**	**Absolute Mean Difference (^{0}C)**	**Critical value**	**Significant**
Pre-Colonial Building type (27.83)	Colonial (28.43)	0.6	0.2264	Significant
	Contemporary (29.27)	1.44	0.2264	Significant
Colonial Building type (28.43)	Pre-Colonial (27.83)	0.6	0.2264	Significant
	Contemporary (29.27)	0.84	0.2264	Significant
Contemporary Building Type (29.27)	Pre-Colonial (27.83)	1.44	0.2264	Significant
	Colonial (28.43)	0.84	0.2264	Significant

Table 6: Post Hoc Comparison for Indoor Relative Humidity (%) of the Building Types

Buildings/ Mean (%)	Group (%)	Absolute Mean Difference (^{0}C)	Critical value	Significant
Pre-Colonial Building type (70.89)	Colonial (67.39)	3.5	2.56	Significant
	Contemporary (66.75)	4.14	2.56	Significant
Colonial Building type (67.39)	Pre-Colonial (70.89)	3.5	2.56	Significant
	Contemporary (66.75)	0.64	2.56	Not Significant
Contemporary Building Type (66.75)	Pre-Colonial (70.89)	4.14	2.56	Significant
	Colonial (67.39)	0.64	2.56	Not Significant

For indoor relative humidity, the null hypothesis was rejected because the absolute mean difference of the paired groups was larger than the critical value calculated as 2.56. The following pairs of groups were found to be significantly different: Pre-colonial building type (M = 71%, SD = 19%) with colonial building type (M = 67%, SD = 17%); pre-colonial building type (M = 71%, SD = 19%) with contemporary building type (M = 67%, SD = 17%). However, there was no significant difference between the pair of colonial building type (M = 67%, SD = 17%) with contemporary building type (M = 67%, SD = 17%). From Table 6 the highest mean difference of 4.4% was observed between pre-colonial and contemporary building types, followed by 3.5% between pre-colonial and colonial building types. The least mean difference of 0.64% was between pre-colonial and contemporary building types and it showed that no significant difference existed in the indoor relative humidity values of the two building types.

In understanding the envelope characteristics of the building types, Lee and Tiong (2007) and Evans (1980) aptly described building envelope as the climate moderator and the interface between external and internal environments. The composition of the different materials and methods of construction of buildings in the pre-colonial, colonial and contemporary historic eras as evidenced from Table 1 were not the same. This corroborates Obinegbo (2011) that forms and types of shelter differ. It was also reported in Koenisberger et al. (1973) that the treatment and selection of materials for the building envelopes influence its thermal performance and aid in the reduction of the heat load. It should be noted that only the contemporary building type had a form of ceiling cover with asbestos sheets. Thermal barriers between roof and interior spaces reduce as low as possible the internal surface temperature of the interior spaces.

From the analyses, there were significant differences indicating that the internal environment of the building types under investigation reacted differently to the totality of transmitted and absorbed heat from the incident solar beam radiation, because of the interplay between the materials of their fabric compositions. In both indoor air temperature and relative humidity cases, pre-colonial building type differed significantly with annual mean indoor air temperature value of 27.83^0C which is lower than colonial and contemporary building types by 0.6^0C and 1.44^0C respectively. Similarly the annual mean relative humidity value of 71% for the pre-colonial building type is higher than 67% and 67% of colonial and contemporary building types respectively as shown in Figure 2.

In all ramifications, the materials for the envelope (wall and roof) composition of pre-colonial building type: mud (*known as 'aja ulo' in Igbo language of eastern Nigeria*), timber (*osisi*), bamboo (*achara*), palm midribs (*ogug*u), thatch (*akilika*) and rope (*udo*), played significant roles in its better thermal performance. As shown in Figure 1, the consistent mean monthly lower indoor temperature values as against those of colonial and contemporary building types made pre-colonial building type to be ascribed as building type with excellent thermal properties (Evans, 1980). Despite the absence of a thermal barrier in the form of ceiling cover, the pre-colonial building type recorded lower indoor air temperature. Also in comparison with annual mean outdoor temperature value of 29.0^0C, the pre-colonial building type modified better the relationship between external and internal environments with a difference of 1.17^0C than colonial and contemporary building types.

The findings of this study aligned with Alhaddad et al., (2013) in Sana'a, Yemen, where the effects of different building materials on indoor thermal comfort of residential buildings were compared and it was found out that indigenous materials performed significantly better than contemporary building materials. Koranteng et al., (2015) in Kumasi, Ghana, studied the effect of different wall materials at different orientations on indoor thermal comfort of residential buildings. The findings differed from this study because it examined only the effects of orientation and wall materials, whereas, the effects of the components of the building fabric on indoor thermal comfort were investigated in this study.

The development of indoor thermal comfort performance of the building types with advancement of time appeared rather worrisome and retrogressive. The mean difference between pre-colonial and colonial was 0.84^0C; pre-colonial and contemporary 1.44^0C. This implies that the systems, materials and forms of contemporary building types ordinarily did not improve the efforts of our forebears if not for the assistance provided by electro-mechanical devices. Despite these inherent opportunities, the traditional practices of our forebears as expressed in these inspired and ingenious buildings of the pre-colonial era are being discarded in favour of contemporary systems, materials and techniques which have continually and negatively impacted on energy consumption and environmental resources as noted by (de Dear & Brager, 1998).

5. CONCLUSION AND RECOMMENDATION

This study investigated the forms and materials of the building envelopes since they constitute the interface between external and internal environments and consequently, control energy efficiency, indoor environment and functional performance of the buildings. The study also observed the indoor air temperature and relative humidity values and determined the differences between thermal performances of the building types spanning pre-colonial, colonial and contemporary historic eras. These relationships and differences were investigated with the aim of drawing lessons from their fabric composition for the advancement of sustainable development in design and construction.

The study revealed that in terms of indoor air temperature and relative humidity, the thermal performances of the building types were significantly different; giving indications that their fabric compositions affected indoor levels of thermal comfort. However, with regards to indoor air temperature, pre-colonial building type performed best when compared with 1.44^0C and 0.6^0C of contemporary and colonial building types respectively. Colonial building type performed better than contemporary building type with a mean difference of 0.84^0C. As per relative humidity, pre-colonial building type recorded higher values than contemporary and colonial building types by 4.14% and 3.5% respectively. There was no significant difference between colonial and contemporary building types in terms of relative humidity. Therefore, it can be interpreted that solar beam radiation on the fabric of pre-colonial building type in Okigwe, Nigeria, yielded lower indoor air temperature which meant cooler indoor environment than colonial and contemporary building types.

As one of the global concerns for sustainable development is the reduction of energy consumption in the construction sector since buildings have been adjudged as major contributors to the global greenhouse gas (GHG) emissions, the study thus, recommends that the materials for roof, wall and floor compositions as in pre-colonial building type should be integrated in the discursive field of the delivery and management of building designs and construction for sustainable development as they possess good inherent indoor thermal comfort qualities that provide acceptable indoor thermally comfortable environment. Furthermore, research and development should be encouraged for the promotion of African-based knowledge systems and its integration into curricula programmes of African centres of learning.

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7 REFERENCES

Adeyemi, E. A., 1987. National variants in modern architecture: Towards evolution of a Nigerian architectural vocabulary. *NIA Journal*, pp. 22-24.

Al horr, Y. et al., 2016. Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable bUILT Environment*, pp. 1-11.

Alhaddad, M. A. & Jun, T. Z., 2013. A comparative study of the thermal comfort of different building materials in Sana'a, Yemen. *American Journal of Engineering and Applied Sciences,* pp. 20-24.

Alrashed, F., Asif, M. & Burek, S., 2017. The role of vernacular construction techniques and materials for developing zero-energy homes in various desert climates. *Buildings,* 7(17), pp. 1-19.

ASHRAE 55, 2004. *ANSI/ASHRAE Standard 55-2004: Thermal environment conditions for human occupancy,* Atlanta Georgia: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Attmann, O., 2016. Sustainable technologies for green buildings: An overview. *Journal of Buildings and Sustainability,* 1(1), pp. 22-34.

Croome, D. J., 1991. The determinants of architectural form in modern buildings within the Arab world. *Building and Environment,* 26(4), pp. 349-362.

Cui, W. et al., 2013. Influence of indoor air temperature on human thermal comfort, motivation and performance. *Building and Environment,* pp. 114-122.

de Dear, R. & Brager, G. S., 1998. Towards an adaptive model of thermal comfort and preference. *ASHRAE Transactions,* 104(1), pp. 145-167.

Djongyang, N., Tchinda, R. & Donatien, N., 2010. Thermal comfort: A review paper. *Renewable and Sustainable Energy Review,* pp. 2626-2640.

El-Betar, S. A., 2017. Towards sustainable buildings in Egypt. *Journal of Buildings and Sustainability*, 1(1), pp. 25-35.

Evans, M., 1980. *Housing, climate and comfort.* New York: Halsted Press.

Givoni, B., 1981. *Man, climate and architecture.* New York: Van Nostrand Reinhold.

Koenigsberger, O. H., Ingersoll, T. G., Alan, M. & Szokolay, S. V., 1973. *Manual of tropical housing and building: Part I Climatic design.* London: Longman.

Koranteng, C., Essel, C. & Amos-abanyie, S., 2015. The effect of different wall materials at different orientations on indoor thermal comfort in residential buildings in Kumasi, Ghana. *Research Journal of Engineering and Technology,* pp. 9-18.

Lee, I. & Tiong, R., 2007. *Examining the role of building envelopes towards achieving sustainable buildings.* s.l., s.n.

Nematchoua, M. K., Tchinda, R. & Orosa, J. A., 2014. Thermal comfort and energy consumption in modern versus traditional buildings in Cameroun: A questionnaire-based statistical study. *Applied Energy,* pp. 687-699.

Nsude, G. C., 1987. *The Traditional Architecture of the Igbo of Nigeria.* Dartford: School of Architecture and Landscape, Thames Polytechnic.

Obinegbo, N. M., 2011. Basic Historical Development in Architecture. In: *Fundamentals in Architecture.* Enugu: Cheston Ltd.

Roaf, S., Crichton, D. & Nicol, F., 2009. *Adapting buildings and cities for climate change: A 21st Century survival guide.* Oxford: Architectural Press.

Wahab, A. B., 2015. Effect of physical characteristics and thermal performance of secondary school built with bricks on adaptive behaviour of its occupants. *Civil and Environmental Research,* 7(1), pp. 55-63.