Thermal Perception of Residents in Housing Developments Built With Laterite Interlocking Blocks in Ado-Ekiti, Nigeria

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Abstract
Designing thermally responsive buildings is a top priority in architecture. Furthermore, tenets of environmental sustainability suggests the use of locally available material as a veritable approach to reduce impact of buildings on the environment. Locally available laterite interlocking blocks has been introduced as a sustainable material by Nigerian Building and Road Research Institute, what is the perception of users of the model building material? This research aims to find out the perception of residents about thermal sensation in housing developments built with laterite interlocking block (LIB) towards popularising locally available materials as a sustainability strategy in the Nigerian building industry. Responses were obtained from one hundred and eight residents of Olusegun Obasanjo's low cost housing estate, Ekiti state, Nigeria, using structured questionnaires in July 2016. The result shows that 51.1% of respondents' living in houses built with LIB prefer houses built with LIB to the conventional sandcrete blocks. In addition, respondents are more comfortable in the residential buildings during the dry season (60.18%) than during the rainy season (48.15%), both the dry and wet season votes are less than the international benchmark of 80% indicating satisfaction with thermal properties of buildings indoors.

Keywords: Comfort, Environment, Housing, Laterite, Sustainability

INTRODUCTION

Historically, laterite has been the most widely used and known material for building construction. Earth is humanity's oldest and most important natural building material (Heathcoat and Moor, 2004; Minke, 2006; Dmochowski, 1990). Supporting the assertion, Dethier (1981) estimated that over 30% of the world population lives in earth built structures. In addition, data from the 2006 Population and Housing Census (NPC, 2006 pg. 318) shows that 19.93% of buildings in Ekiti state Nigeria have walling material made up of earth or mud. Aghimien, Makanjuola and Adegbembo (2016, pg.210) in the assessment of using compressed, stabilized interlocking earth blocks in Lagos and Ondo States, Nigeria, noted that top drivers for the use of LIBs are: aesthetic nature of the system, low cost of the material, suitability of the construction, reduction in cost of finishes / maintenance, time saved during construction and the availability of raw materials in that order, the major barriers are: high cost of machine, lack of skilled machine operators, lack of trained personnel handling production, low acceptability amongst social groups, delays in the production process and absence of trained masons for wall construction. Other barriers according to Minke (2006) is that earth is not water resistant, furthermore, it shrinks when drying, this can however be overcome by stabilising the earth material with cement as done with LIB. The following minimum specifications for the production of the interlocking blocks are: a bulk density of 1810 kg/m3, a water absorption of 12.5%, a compressive strength of 1.65 N/mm2, this can be achieved with a minimum recommended cement content fixed at 5% (NBRRI, 2006, p.39; Raheem, Momoh and Soyingbe, 2012, p.80).

Some of the advantages of using LIB for building construction are high durability and impact strength than those constructed from cement block (Agbeyo, 2009), the aesthetic and attractive nature reduces the need for painting and plastering, which in turn reduces construction cost (Oshike, 2015). The block has excellent thermal values, that is the ability to absorb and hold heat and at 92-95% clay, they are thermally superior to most other products. Another advantage is high construction speed (Assiamah, Abeka and Agyeman, 2016) - mortar less technology results in a reduction of construction duration of up to 60%, furthermore, transport costs are minimized since blocks are produced on site. Furthermore, LIB is perceived to have an advantage in its production and assemblage which requires little skill, which can be acquired within a short period of training (Oshike 2015).

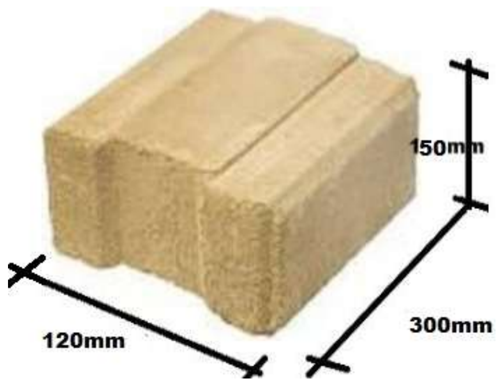

Figure 1. A picture showing Laterite Interlocking Block, retrieved from Hydraform (2016)

Alternative middle level technology such as the use of laterite interlocking blocks made up of earth material should enhance housing. Sustainable housing aims to address biological (clean air and water), psychological (satisfaction, contentment, prestige, privacy, choice, freedom, security) and social needs (interaction with others, human development, cultural activities) according to Olotuah (2009). Sustainable housing involves providing gradual, continual and replicable process of meeting the housing needs of the populace, the vast majority of the poor are incapable of providing adequately for themselves informs Adedeji, Taiwo, Olotuah and Fadairo (2011). Housing is defined by the free dictionary as “a structure serving as a dwelling for one or more persons, especially for a family”. Sustainability in housing developments can be achieved through the use of building materials which are reasonably priced and readily available for use.

The challenge for building designers in Nigeria and Ekiti state specifically is to develop acceptable models of traditional building materials and methods. The aim of the research is to study the perception of residents about thermal sensation in housing developments built with laterite interlocking block (LIB) towards popularising locally available materials as a sustainability strategy in the Nigerian building industry. An example of such acceptable model is the Nigerian Building and Road Research Institute (NBRRI) building block (Alli, 2010, pg. 46), otherwise known as laterite interlocking blocks (LIB). What is the perception of residents from the Olusegun Obasanjo Housing Estate, Ado Ekiti concerning thermal performance of the LIB? This work is important towards the adoption of LIB as part of sustainable housing development policy in Nigeria.

Housing Situation Nigeria

A large percent of Nigerians now live in urban centres. Moreover, of the available housing units, only 33% of houses can be considered to be physically sound (Olotuah and Taiwo, 2013). The housing stock is generally overcrowded with a ratio of 1000 inhabitants to 23 housing units and that majority of the populace still lack accommodation (Mabogunje, 2004). Further examples of qualitative housing difficulties in Nigeria includes, but is not limited to: shelter susceptible to inclement weather, lack of safe water supply, lack of efficient drainage systems, poor sewage and refuse disposal techniques, poor access roads. Quantitative needs consist of high cost of building materials and labour, limited access to finance and land are also critical. Summarily, the housing deficit in Nigeria is expected to be as high as 12.7million by the year 2020 (Olayiwola 2002).

The Concept of Sustainable Development

Sustainable development was said to be first introduced by Ward & Dubos (1972). Sustainable development is popularly defined as any design which "meets the needs of the present without compromising the ability of the future generations to meet their own needs" (World Commission on Environment and Development (WCED, 1987). Sustainable development is a very broad concept. The key environmental issues driving the sustainable development discourse are enlisted: climate change, water availability, pollution, soil erosion / flooding, damage to ecosystems, resource depletion, desertification and increase in population density (Atkinson, Yates and Wyatt, 2009, p.2-3). In the building industry, tools have been developed for measuring sustainable development, the popular ones are: British research establishment environmental assessment method (BREEAM 2017) and leadership in energy and environmental design (USGBC, 2009).

A conceptual framework by which architecture can coexist with the goals of sustainability was proposed by Kim and Rigdon (1998. The three levels of the framework (Principles, Strategies, and Methods) correspond to the three objectives of architectural environmental education: creating environmental awareness, explaining the building ecosystem, and teaching how to design sustainable buildings. The principles of sustainability as proposed by Kim & Rigdon (1998) in architecture are:

I. **Economy of Resources: -** The principle focuses on the reduction, reuse, and recycling of the natural resources that are input to a building.
II. **Life Cycle Design: -** This principle recognizes environmental consequences of the entire life cycle of architectural resources, from procurement to return to nature.
III. **Humane Design: -** This is perhaps the most important, principle of sustainable design. While economy of resources and life cycle design deal with efficiency and conservation, humane design is concerned with the livability of all constituents of the global ecosystem, including plants and wildlife.

Sustainable Building Materials

Sustainable building materials are described in terms of having low or no impact on the environment, during the extraction, production, construction use, repair, refurbishment or replacement (usually at the end of product life). Citing examples of hard floor finishes, ceramic floor tiles, has a better environmental rating than synthetic rubber tiles Anderson, Shiers and Sinclair, 2002). Also, the LIB can be used as a sustainable product, because it cuts down carbon dioxide emissions through its reduction in cement content. The use of LIB as a sustainable material is supported by Oluigbo (2012, p.250), suggesting that the use of locally available materials contributes to economic sustainability through cost reduction, to the socio cultural sustainability by reflecting local identity and to environmental sustainability by reducing carbon cost of transportation and production of cement.

Thermal Comfort of Building Residents in the Tropics

A number of researchers (Ogunsote, 2012; Ajibola, 2001; Adebamowo, 2013) have worked extensively on thermal comfort as a subject in Nigeria, with derivable such as delineation of climatic zones in Nigeria with respect to building design; characteristics of bioclimatic buildings, architectural principles for low energy design. In addition Adedeji *et al* (2011) worked on LIB as an alternative construction material, however a study of the thermal comfort of users living within residences built with laterite interlocking blocks is missing in literature, hence the need for this work. In the tropics, rather than heat up the buildings, cooling through active and passive means is of importance, it is therefore good design practice to reduce energy consumption by making buildings fit tropical climate (Bay and Ong 2006, p.226).

Figure 2. A map showing Ekiti state in the context of Nigeria, retrieved from Map of Nigeria (Courtesy Wikipedia)

METHODOLOGY

The strategy engaged in this research is the survey method, which is cross-sectional (Creswell, 2003). The survey was carried out in June, 2016. Descriptive statistics such as tables, pie chart and bar chart was used for the analysis. A total of one hundred and eight (108) questionnaires was administered to one adult per building within Olusegun Obasanjo housing estate Ekiti state. On each street, for every five buildings, the first four buildings were selected, leaving out the next one building until the quota for each typology was filled up.

Ekiti State Overview

Ekiti state was declared a state in the Nigerian Federation October 1, 1996 alongside five others by the military regime of General Sani Abacha. The state was carved out of the territory of old Ondo State. Ekiti State is located within the tropics. It is located between longitudes 40º 51' and 50º 45' East of the Greenwich meridian and latitudes 70º 15' and

80º 51' north of the Equator. It lies south of Kwara and Kogi State, East of Osun State and bounded by Ondo State in the East.

Olusegun Obasanjo Housing Estate, Ekiti Statte

The Olusegun Obasnjo estate was conceived by the Federal Government of Nigeria as a part of the Presidential mandate to construct 500 housing units in each state of the federation and the Federal Capital Territory. Production of building materials of indigenous origin by NBRRI was given logistic and material support by the state government. Local participation was also actively encouraged in the project (Olotuah and Taiwo, 2013).

The research population is 148 buildings. Two categories of building type is evident in the estate, 25 - two bedroom bungalows and 123 - three bedroom bungalows. The sample size for a population of approximately 148 according to Krejcie and Morgan table (1970, p.608) at 95% confidence level is 108 (see Table 1).

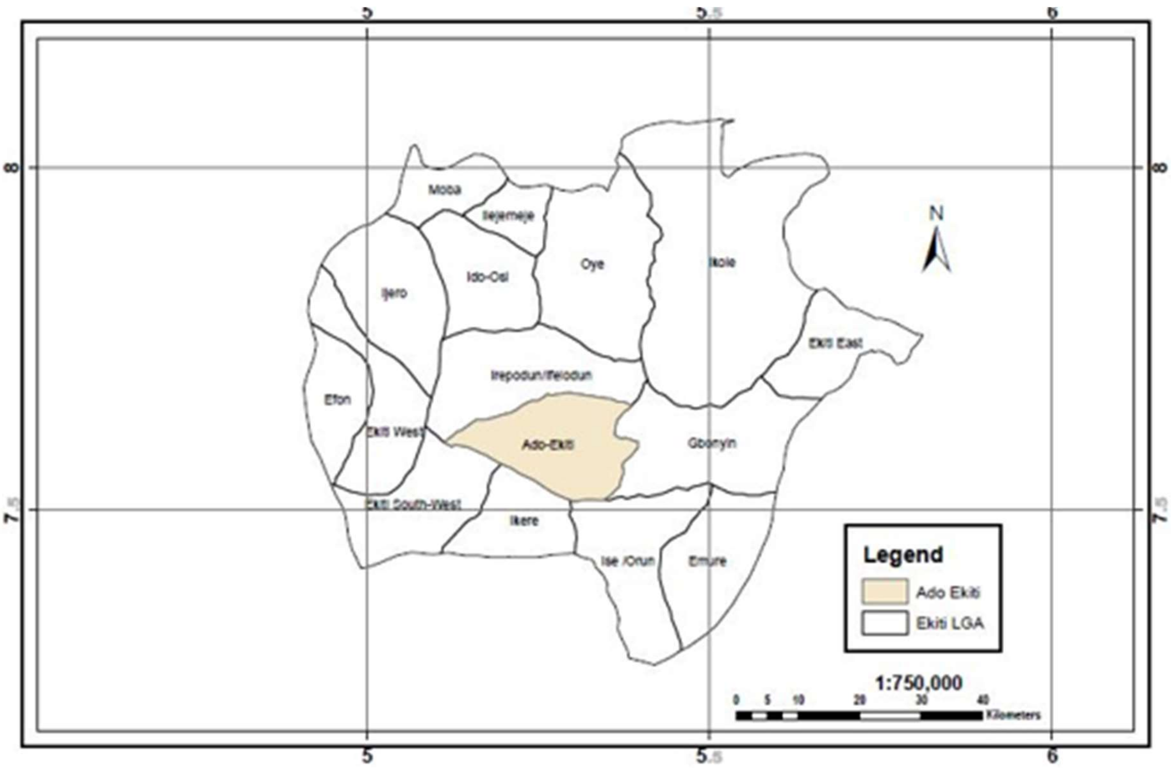

Figure 3. Map of Ekiti State showing Ado Ekiti Local Government Area shaded, retrieved from Google Earth (2016), reproduced using ARCGIS software.

Table 1. Breakdown of housing units (population of study and sample) in Olusegun Obasanjo Estate retrieved from analysis of field study (2016)

S/n	Building type	Total number	Sample	Percentage
1	2 bedroom bungalow	25	18	72.0
2	3 bedroom bungalow	123	90	73.17
Total		148	108	72.97

Figure 4. A satellite image showing Olusegun Obasanjo estate, Ekiti state, courtesy Google Earth (2016)

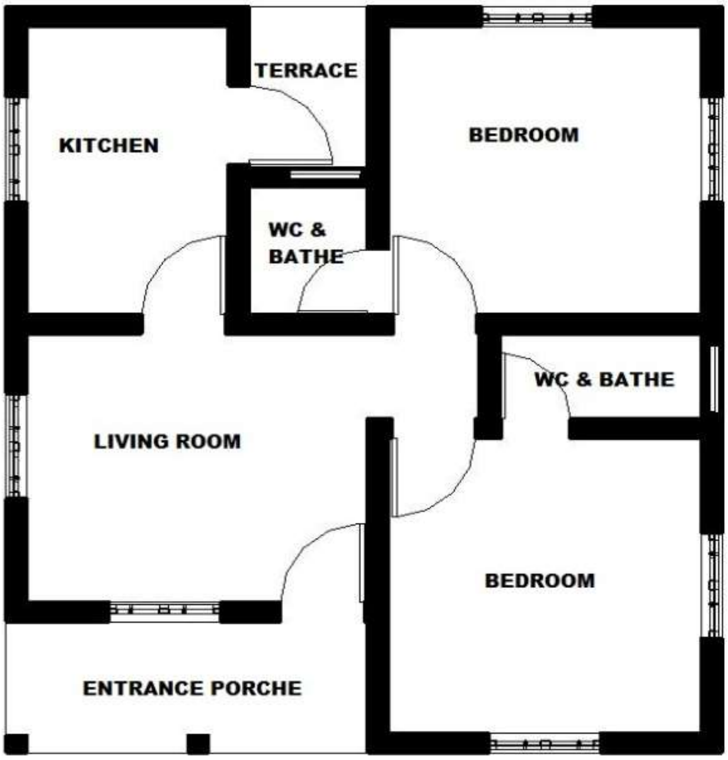

Figure 5. A two dimensional drawing showing the ground floor plan of two bedroom bungalow with an area of 75.15m2 (source: field study 2016).

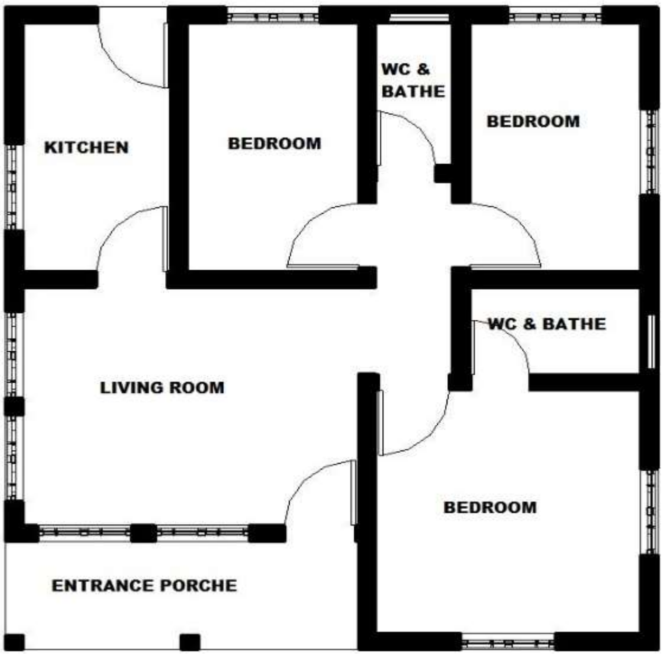

Figure 6. A two dimensional drawing showing the floor plan of three bedroom bungalow, typology one, with an area of 84.54m2 (source: field study 2016).

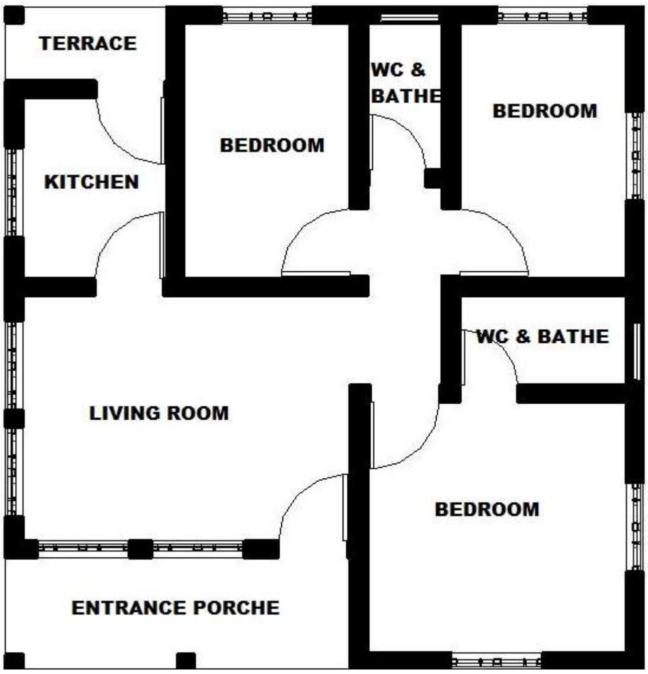

Figure 7. A two dimensional drawing showing the ground floor plan of a three bedroom bungalow, typology two with an area of 84.54m2 (field study 2016).

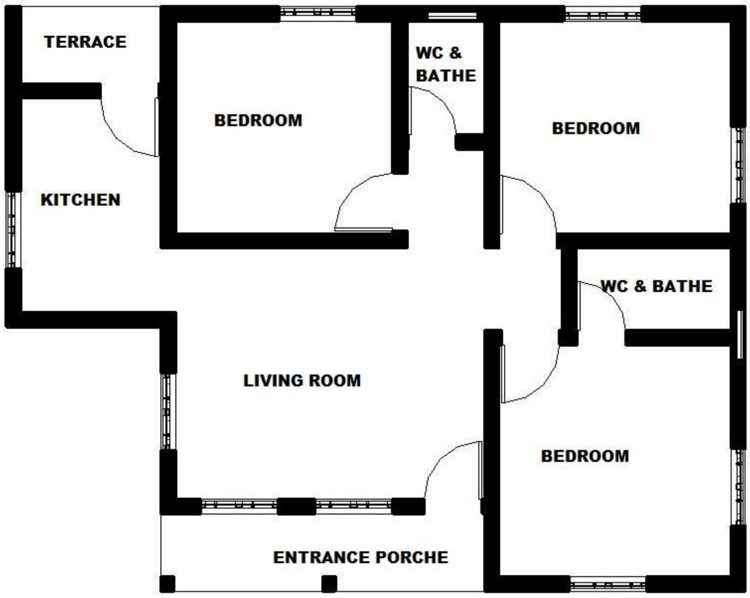

Figure 8. A two dimensional drawing showing the floor plan **OF THREE BEDROOM BUNGALOW** special for typology one with an area of 107.29m2 (source: field study 2016).

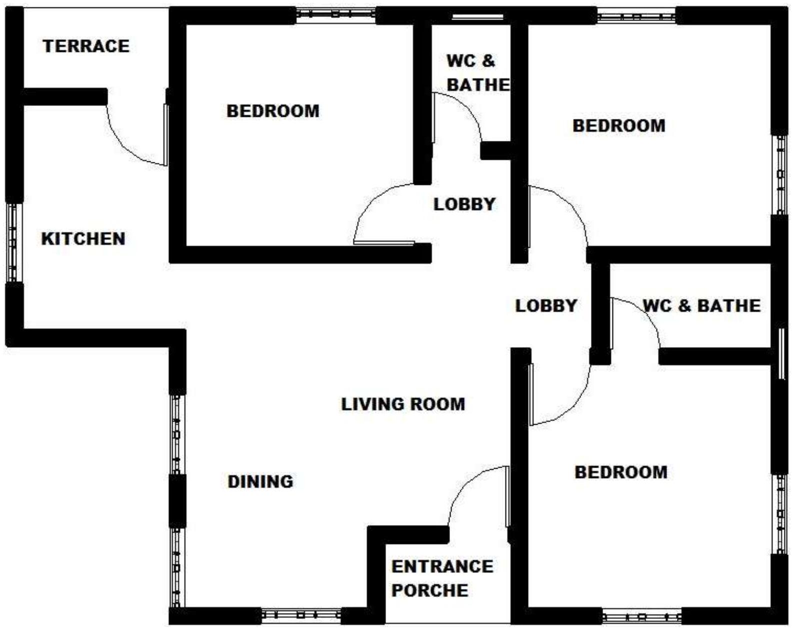

Figure 9. A two dimensional drawing showing the ground **FLOOR PLAN OF THREE BEDROOM** bungalow special typology 2, with an area of 107.29m2 (source: field study 2016).

Figure 10: A picture showing a three bedroom bungalow special for medium class in the estate (source: field study 2016).

RESULTS AND DISCUSSION

Socio economic characteristics of respondents

This section gathered information on the general characteristics of the respondents. The percentage of male compared to female respondents in the estate are 55.56% and 44.44% respectively (see Table 2). Respondents are adults above eighteen years that participated willingly. The breakdown of the age of respondents shows that 46.30% of the respondents are between the ages 18- 36, 43.52% are between ages 37- 54 and 10.18% are between ages 55-72. The highest level of education attained by the respondents ranges from 2.78% of the respondents being primary school certificate holders, 12.96% secondary school certificates, while 84.26% are tertiary school graduates with OND, HND, Bachelors or PGD, MTech., or PhD. This result indicates that there is a high level of literacy among the residents of the estate that is all respondents have one form of formal education or another. Analysis of the income stratification of residents per month reveals that 20.37% of the respondents earn below the minimum income acceptable in Nigeria (₦18,000), 27.78% earn between ₦18,000 and ₦36,000, 12.96% of respondents earn between ₦37,000 to ₦54, 000, while 38.89% earn around ₦55, 000 and above. The data indicates that majority of the respondents, which is 79.63% earn higher than the minimum wage. The housing tenure of respondents shows that 31.48% are owner occupiers while 68.52% are tenants indicating that a larger percentage of residents are tenants. Summary of residents' duration of occupancy within the estate shows that, 63.89% have stayed in the estate for a period between 1-5 years, 34.26% have lived in the estate for a period between 6-10 years, while only about 1.1% affirmed living in the estate for a period above 10 years.

Table 2. Socio economic characteristics of respondents in Olusegun Obasanjo Estate retrieved from analysis of field study (2016)

S/N	Category	Questionnaire Item	Quantity	percentage
	Socio economic characteristics of respondents			
1	Gender	male	60	55.56
		female	48	44.44
	Total		108	100
2	Age	18 – 36	50	46.30
		36 - 54	47	43.52
		54 - 72	11	10.18
		72 years and over	0	0
	Total		108	100
3	Highest levels of education attained by respondents	No formal education	0	0
		Primary education	3	2.78
		Secondary education	14	12.96
		Tertiary education	91	84.26
	Total		108	100
4	Housing Tenure	Tenant	74	68.52
		owner occupier	34	31.48
	Total		108	100
5	Income stratification of the residents per month	N1 –N 18,000.00	22	20.37
		N18,000.00 – N36,000.00	30	27.78
		N36,000.00 – N54,000.00	14	12.96
		N54,000.00 – N72,000.00	42	38.89
	Total		108	100
6	Duration of occupancy	1-5 years	69	63.89
		6-10 years	37	34.26
		11 years and above	2	1.85
	Total		108	100

The intent of NBRRI is to popularise the use of LIB for sustainable construction in Nigeria, this informs the technical support received from NBRRI by the state government. To which extent does the material used for the wall construction, LIB influence residents' choice staying in the estate? 64.7% of the respondents informs that the LIB played a role in their choice of the estate for residence while 35.3 said it was not at all a motivating factor in their choice of the estate. It can be deduced that since 64.7% of the respondents selected the estate based on the LIB used for construction, it simply indicates that positive attributes of the material such as aesthetics and reduction in cost of finishes of the LIB is a motivating factor.

Extent of the Influence of LIB on selection of the estate for living

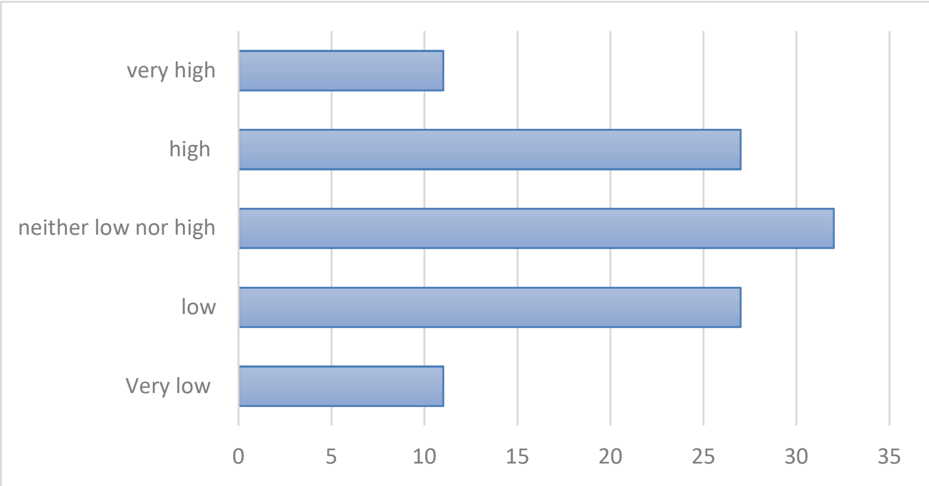

Figure 11. A bar chart showing the analysis of the extent of the influence of lib on the selection of Olusegun Obasanjo estate for living, retrieved from analysis of field survey (2016).

Thermal comfort of residents in the building interior

Fanger (1973) provided an approach for the assessment of thermal comfort in interior spaces using a rating scale. The rating scale informs that between the range of cool and warm, respondents are satisfied with the condition. This approach would therefore be used to determine the satisfaction level of occupants in each of the spaces. Thermal comfort according to American National Standards Institute, American Society of Heating, Refrigeration and Air-conditioning Engineers (ANSI / ASHRAE 55, 2013) is "that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation". To achieve thermal comfort in warm humid climates, restricting the flow of heat into a building can be achieved through low thermal capacity walls, high insulation and reflective roofs combined with good ventilation (Ogunsote, n.d.).

Thermal comfort of residents during raining season

Descriptive summaries from Table 6 shows that 34.26% of respondents specified that the interior of the space is cold, 13.89% informs it is cool. On the other hand, there was no response for the hot sensation, while 3.70 % of the respondents selected warm sensation. 25.93% indicated that the building interior is neutral, 17.59% specified it is slightly cool while 4.63% indicated slightly warm sensation. The result indicates that the total response for the neutral sensation in the estate according to ANSI / ASHRAE (2013) shows that 48.15% of respondents are satisfied with the thermal capacity of the LIB in Ado Ekiti during the period of their residence in the estate, while 51.85% is dissatisfied.

Table 6. Analysis of the thermal sensation felt by occupants in the building during raining season analysed from field study (2016).

S/N	Thermal sensation of occupants in the building interior overall during the raining season	Frequency	Percent
1	Cold	37	34.26
2	Cool	15	13.89
3	Slightly cool	19	17.59
4	Neutral	28	25.93
5	Slightly warm	5	4.63
4	Warm	4	3.70
5	Hot	0	0
Total		108	100.0

Thermal comfort of residents during the dry season

Thermal sensation felt by occupants is captured in the ratios presented in Table 7, where 10.19% voted that the living interior of their spaces is cold, 9.26% described the building interior as cool. On the other hand, 15.74% informs that the interior of the buildings is warm while only 4.63% indicated the interior is hot. Assessing the comfort scale which includes adding up the slightly cool, neutral and slightly warm sensations for residents in the estate according to ANSI / ASHRAE (2013) shows that 60.18% of respondents are satisfied with the thermal capacity of the LIB in Ado Ekiti during the period of their residence in the estate. The result therefore indicates that 39.82% are uncomfortable within the space during the dry season.

Table 7. Analysis of the thermal sensation felt by occupants in the building during dry season, retrieved from analysis of field study (2016).

S/N	Thermal sensation of occupants in the building interior during the dry season	Frequency	Percent
1	Cold	11	10.19
2	Cool	10	9.26
3	Slightly cool	13	12.04
4	Neutral	31	28.70
5	Slightly warm	21	19.44
6	Warm	17	15.74
7	Hot	5	4.63
Total		108	100.0

Preference of Users for Sandcrete or Libs

Some residents (36.4%) prefer sandcrete block for their house construction, while 51.1% prefer LIBs for housing development, in the same vein 12.5% of the respondents were undecided. The result obtained indicates that for residents living in houses constructed with LIB within the estate, 51.1% have preference for LIB over the commonly known sandcrete block (see figure 12).

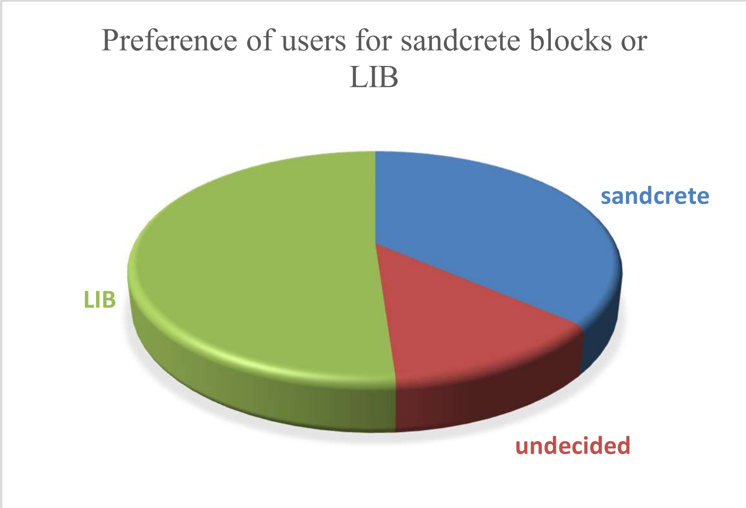

Figure 12. Bar chart showing the analysis of users' preference for LIB compared to sandcrete blocks retrieved from analysis of field survey (2016).

CONCLUSION

The analysis from this study shows that 51.1% of respondents' living in houses built with LIB in Obasanjo Estate, Ado Ekiti prefer houses built with LIB to the conventional sandcrete blocks. Furthermore, 64.7% of respondents indicated that laterite played a role in their choice of the estate for residence. Satisfaction of users using LIB as walling materials is expected to be associated with thermal sensation of slightly warm, neutral and slightly cool as posited by ANSI / ASHRAE 55 (2013). Within the research area, respondents are more comfortable in the residential buildings during the dry season (60.18%) than during the rainy season (48.15%). Both the dry season and wet season votes are less than the international benchmark of 80% votes of sample residents. Suggestions for further researches includes assessments in other estates built with LIB located in other local governments or other climatic zones in Nigeria.

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Appendix

Table for determination of sample size of a known population at 95% confidence level retrieved from Krejcie and Morgan (1970), where *N* is population size and *S* is sample size.

N	*S*	*N*	*S*	*N*	*S*
10	10	22	14	1200	291
15	14	23	14	1300	297
20	19	24	14	1400	302
25	24	25	15	1500	306
30	28	26	15	1600	310
35	32	27	15	1700	313
40	36	28	16	1800	317
45	40	29	16	1900	320
50	44	30	16	2000	322
55	48	32	17	2200	327
60	52	34	18	2400	331
65	56	36	18	2600	335
70	59	38	19	2800	338
75	63	40	19	3000	341
80	66	42	20	3500	346
85	70	44	20	4000	351
90	73	46	21	4500	354
95	76	48	21	5000	357
100	80	50	21	6000	361
110	86	55	22	7000	364
120	92	60	23	8000	367
130	97	65	24	9000	368
140	103	70	24	10000	370
150	108	75	25	15000	375
160	113	80	26	20000	377
170	118	85	26	30000	379
180	123	90	26	40000	380
190	127	95	27	50000	381
200	132	100	27	75000	382
210	136	110	28	1000000	384