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# Effect of Physical Characteristics and Thermal Performance of Secondary School Built with Bricks on Adaptive Behaviour of Its Occupants

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**Abstract**
The design and mode of construction of building affect its thermal behaviour and influence how the occupants respond to its internal conditions. This study examined physical characteristics and indoor environmental conditions of a secondary school built with bricks and assess adaptive behaviour of the occupants. A secondary school located in Ibadan Metropolis built with bricks was used as a case study. Data were collected with the aid of objective and subjective instruments. It was shown that the materials of construction; bricks, orientation, vegetation and nature of landscape of the school compound aided its thermal performance. The results showed that the mean values of indoor air temperature and relative humidity, 27.9$^0$C to 31.4$^0$C and 28.0% to 80.3% were more than the standard values of 26$^0$C to 28$^0$C and 30.0% to 70.0% respectively required for sedentary activity. It was shown that the three most ranked adaptive measures adopted by the occupants were the wearing of thick clothe during cold season, wearing of light clothe during hot period and full opening of doors with an index value of 4.16, 4.06 and 4.00 respectively. The least ranked adaptive behaviour was the act of moving out of the staffroom/classroom which has an index value of 2.36. The study recommended that proper consideration must be given to the relevance of passive features and materials of construction that will enhance occurrence of comfortable environmental conditions and also aid efficiency and productivity of the occupants indoor.
**Keywords:** School building, Occupants, Physical and design features, indoor environment condition, Adaptive measures.

## INTRODUCTION

An extremely punctual definition of macroclimate requirement is demanded in order to provide thermal-hygrometric comfort conditions in the working and living environments (Buratti and Ricciardi, 2006). Buildings constitute a substantial percentage of most educational institutions' assets, user needs and operating costs. The performance level of this resource is therefore very critical to educational effectiveness. Educational buildings are designed and built to meet specific or group of needs already determined to a large extent before implementation. The operating performance of the thermal behaviour of the materials used to construct buildings has much impact on the expected comfort and productivity level of the occupants (Okolie, 2006). In educational institutions, the materials of construction of buildings constitute the essential features that enable the teacher and the students to be productive.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (2004) defined thermal comfort as that condition of mind which expresses satisfaction with the thermal environment. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate and thus maintaining thermal equilibrium with the surroundings. It has been long recognized that the sensation of feeling; hot or cold, is not just dependent on air temperature alone (Mors, 2010). The most commonly used indicator of thermal comfort is air temperature as it is easy to use and most people can relate to it. Although, it is an important indicator to take into account, air temperature alone, is neither a valid nor an accurate indicator of thermal comfort or thermal stress. Air temperature should always be considered in relation to other environmental and personal factors (Nevin, 2003).

It has been observed that warm-humid climate is subject to environmental challenges characterised by high temperature and humidity. In view of this, Croome (1991) noted that comfortable indoor environment should be provided for human activities and human aspirations can only be met when climate, buildings and people are in balance. Thermal comfort expresses satisfaction with thermal environment (Son *et al*., 2008). The term, thermal comfort has been seen essentially, as a subjective term. However, there has been extensive research in this area and a number of indices exist that can be used to assess thermal comfort (Shek and Chan, 2008). Comfort can be defined as a state of physical and mental well-being (Hyde, 2000). Thermal comfort is a subset of the broad definition of comfort and it relates human and environmental factors.

Thermal comfort is very important to many work-related factors as it can affect distraction level of workers, and in turn, affect their performance and productivity at work. The study of thermal comfort has taken a psychological dimension along with the initial physiological approach. The physiological concept laid the foundation for relating the physical parameters of an environment to the thermal state of the body physiology and health; the human subjective psychology gave insight into the human experience of thermal comfort (Fisk 1982; Szokolay 2008). This has made the study of thermal comfort of buildings to be a matter of discourse amongst researchers in Nigeria. Past works of Sharma and Ali (1986); Ogunsote and Prucnal-Ogunsote (2002); Ajibola (2001) and Adunola (2012) have largely looked at the thermal performance of buildings used majorly for residential purposes. However, there is paucity of studies on the thermal behaviour of educational buildings, and in particular, how schools built with bricks could affect internal conditions of the buildings and comfort of the occupants. In view of this, the specific objectives of the study are to examine physical characteristics and indoor environmental conditions of school built with bricks and assess occupants' adaptive behaviour.

## THE STUDY AREA

The study was carried out in a senior secondary school, the Government Senior Secondary School, Orita-Aperin Area of Ibadan. The school was constructed with the use of oven-baked bricks. The location of the case study, Ibadan, had been the capital city for the defunct Western Group of Provinces (1939), Western Region (1954), Western State (1967), the old Oyo State (1976), and the present Oyo State (1991) after Osun State was carved out (Aderemi, 2004). The city of Ibadan is located approximately between latitude 7.37º and 7.67º North of the Equator, and between 3.88º and 4.17º East of the Greenwich Meridian. Ibadan is about 145 kilometres from Lagos (the former Federal Capital of Nigeria) by road, and about 345 kilometres northeast of Abuja (the current Federal Capital City) as the crow flies. It is directly connected to many towns in Nigeria and its rural hinterland by a system of roads, railways and air routes. The first motorable road in Nigeria was constructed from Ibadan to Oyo in 1906 while the railway system which began in 1896 from Lagos to Kano in 1911 passed through the city (Fadare, 1997). By all standards, Ibadan is an important socio-economic, administrative, educational and industrial centre (Fadare and Wojuade, 2007).

The land use pattern compares with what obtains in other large cities in Nigeria. The general land use pattern of Ibadan metropolitan area shows a clear distinction; purely non-agricultural use for urban Ibadan, and agricultural use for the rural Ibadan. Residential land use is the most predominant among all land uses in the built-up part of Ibadan. The metropolitan area of the city has one of the highest population densities in the country and the mostly densely settled areas remain the central and indigenous core of the city (Ayeni, 1994). The population growth of Ibadan has been remarkable. The population rose from the estimated 100, 000 in 1851 to 175, 000 in 1911. Between 1911 and 1921, it increased at about 3.1 per cent per annum to 238,075. The rate of increase between 1921 and 1931 was 0.5 per cent per annum while it was only 0.8 per cent per annum for the period between 1931 and 1952 when the population rose from 387, 133 to 459, 196 (Ayeni, 1994). The census conducted in 2006 indicated that Ibadan has a population figure of about 2,550,593 (FGN, 2009).

## RESEARCH METHODOLOGY

Thermal comfort study requires two important groups of data, the objective and subjective measurement data. Since human perception is not as simple as stimulus response phenomenon, this field survey attempted to observe and collect some data that were believed to be essential to understand complex human perception, behaviour and background. The equipment which was used for the objective measurement was the techno humidity meter. It was used for measuring air temperature, relative humidity and dew point. It has an accuracy of $\pm 0.5^oC$ and 0.5% for temperature and relative humidity readings respectively. Digital anemometer was used for measuring the wind speed. All these equipment were calibrated before use to ensure reliability and accuracy of the readings. The instruments used met the ISO 7730 requirements (ISO, 1994). In most cases, thermal uniformity was difficult to achieve in most classrooms and staff rooms. Hence, the measurement of environmental parameters was conducted at various points in the occupied zone. The parameters were measured at about 1.1 meter above the floor and this represents the height of occupants at the seated level. The average environmental parameters in the occupied zones were taken for analysis (Plate 1). The measurements of the parameters were conducted between 8:00 a.m. and 2:00 p.m. for the recording of internal environmental parameters such as relative humidity, dew point, air temperature and wind speed and the mean values of their readings were presented.

The subjective instrument used included the administration of questionnaires which captured responses from the selected occupants of the schools. The respondents were asked to give response on the adaptive measure or behaviour they use when they are in the classroom/staffroom by using a scale of 1-5; with 1- being not at all important and 5- being very important. The subjective instrument, questionnaire, was complemented with the use of site visits and observation of the physical features of the school on how it could affect thermal response of the occupants. The data collected were analysed with the aid of relevant descriptive and inferential statistical methods.

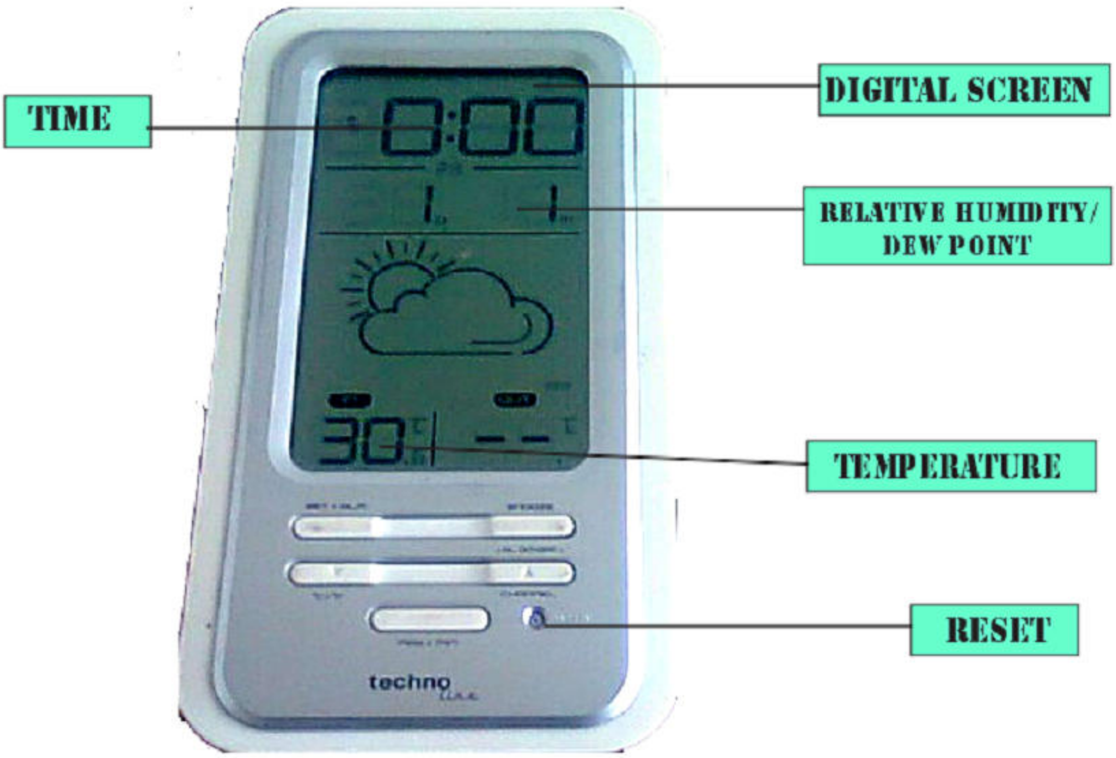


**Plate1. Techno Meter**

## RESEARCH FINDINGS

### General Information about the Occupants

A total number of 70 questionnaires that focused majorly on the thermal response of the occupants of the school, the staff and students were administered. Out of the questionnaires, 50 were administered on the students and 20 on the staff of the school. Out of the respondents, 20 (28.60%) were males and 30 (42.90%) were females in the selected classroom while 8 (11.40%) were male teaching officers and 12 (17.10%) were female teaching officers (Table 1). The educational inclination of the students shows that majority of the occupants, 50 (71.50%) are science students while 11 (15.70%) of the respondents are senior teaching officers and 9 (12.80%) are junior teaching officers respectively. It is shown that the age bracket of the students and staff is between 15-20years and 30-45years respectively. The occupants always engaged in moderate light work (1.2met) during the working period. Therefore, the activity level of all the subjects involved in the study was taken as 1.2 met (70 W/m$^2$). This is according to the value recommended by the International Standard Organisation (ISO-7730, 1994). It was also found that most of the respondents stayed in their rooms for a period, not less than 7 hours a day. This was because the school opened by 7.00am and closed by 2.00pm during which the assembly process and break periods were held as stipulated.

**Table 1: Profile of the respondents**

| Feature of the Respondent | | Classroom | Staff Room | Total |
|---|---|---|---|---|
| Gender | Male | 20 (28.60%) | 8 (11.40%) | 28 (40.00%) |
| | Female | 30 (42.90%) | 12 (17.10%) | 42 (60.00%) |
| Status of Occupancy | Student | 50 (71.50%) | - | 50 (71.50%) |
| | Senior Teaching officer | - | 11 (15.70%) | 11 (15.70%) |
| | Junior Teaching officer | - | 9 (12.80%) | 9 (12.80%) |
| Age (Years) | Maximum | 20 | 60 | 40 |
| | Minimum | 15 | 30 | 23 |
| | Mean | 17.5 | 45 | 31.5 |

**Physical and locational characteristics of the school**

The Plates 2, 3, 4 and 5 show the design features and locational characteristics that might impact thermal comfort of the selected classroom and staff room of the secondary school. The selected classroom and staff room in the study area are located in the east-west direction. The implication of this design strategy is that, it will ensure that the school buildings have access to the prevailing wind. Shading of external windows is provided by natural landscaping such as trees that provide oxygen into the buildings and collect carbon dioxide from the building that is useable by the vegetation for its growth. There are car parks around the selected school buildings absorb heat from the sun and emit it back when the sun sets. This therefore has an impact on the indoor thermal environment of the occupants. Also, tall vegetation around the school's buildings serve as shades to the entire school buildings; provide both classroom and staff room with air circulation, and also serve as wind breakers. The school does not have screen wall which would have reduced direct access to solar heat gain from the sun. However, the school's corridors are well opened and this makes it possible to increase the quality and quantity of natural light indoor (Plate 6). The school has open spaces that are grassed and well landscaped. This made the plant growth to influence both air temperature and the mean radiant temperature (Plates 2 and 3).

The roof covering used in the school was the long span aluminium roofing sheet; the ceiling spaces were covered with the asbestos-free, fibre cement ceiling boards; the windows were made up of louvre blades of different sizes. In the staffrooms and classrooms, fluorescent bulb was used as the lighting fitting and ceiling fans were fixed to the soffit of the suspended slab so as to complement natural ventilation process indoor (Plates 2,3, 4 and 6). The classrooms and staffrooms have overhang that provide weather protection, and thus keep the sun from heating classroom and staff room directly. These physical features of the school also assisted in the contributory roles of the constituent material of constructing the school to its thermal performance and the probable adaptive behaviour of the occupants.

**Plate 2: Vegetation and landscape of compound of the school**

**Plate 3: East-West direction of the school's building**

**Plate 4: Teaching going on in a classroom of the school built with bricks**

**Plate 5: A teacher performing a task in the staffroom**

**Plate 6: Corridor of the classroom**

**Indoor Environmental Conditions of the School Buildings**

The measurements majorly captured four parameters; air temperature, relative humidity, dew point and air velocity. Tables 2 and 3 present the summary of environmental parameters in the selected classroom and staff room of the secondary school buildings built with brick. The profile of the measurements indicated that indoor air temperature and relative humidity which were between 27.9$^0$C - 31.4$^0$C and 28.0% - 80.3% and the data at each location seems to be consistent and of similar pattern. From the data obtained, it is obvious that most of the temperature and relative humidity values exceeded the standard for sedentary activity during dry season. The temperature specified by the standard should be between 26°C and 28°C, and relative humidity should be between 30% and 70% (ASHRAE Standard 55- 2004).

Table 2: Values of the measurements taken in the classroom in the morning and afternoon sessions

| Parameter | Classroom (Morning Session) | | | | Parameter | Classroom (Afternoon Session) | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Maximum | Minimum | | | Mean | Maximum | Minimum |
| Air temperature (°C) | 28.60 | 29.20 | 27.90 | | Air temperature (°C) | 30.40 | 31.40 | 29.30 |
| Relative humidity (%) | 65.30 | 80.30 | 50.20 | | Relative humidity (%) | 33.10 | 38.20 | 28.00 |
| Dew point | 19.60 | 22.37 | 16.80 | | Dew point | 15.80 | 16.60 | 15.00 |
| Air velocity (m/s) | 0.14 | 0.28 | 0.00 | | Air velocity (m/s) | 0.10 | 0.20 | 0.00 |

Table 3: Values of the measurements taken in the staffroom in morning and afternoon sessions

| Parameter | Staffroom (Morning Session) | | | | Parameter | Staffroom (Afternoon Session) | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Maximum | Minimum | | | Mean | Maximum | Minimum |
| Air temperature (°C) | 28.50 | 29.10 | 27.90 | | Air temperature (°C) | 29.80 | 30.60 | 29.00 |
| Relative humidity (%) | 64.30 | 76.00 | 52.60 | | Relative humidity (%) | 33.20 | 36.80 | 29.60 |
| Dew point | 18.90 | 21.00 | 16.80 | | Dew point | 15.95 | 16.30 | 15.60 |
| Air velocity (m/s) | 0.07 | 0.14 | 0.00 | | Air velocity (m/s) | 0.00 | 0.00 | 0.00 |

## ADAPTIVE BEHAVIOUR OF RESPONDENTS

The adaptive actions taken by respondents were analysed and the summary of results shown in Table 4. The findings indicated that the larger proportion of respondents utilized the adaptive opportunities available to them. The adaptive action that was utilized most by respondents was wearing of thick clothe during cold period with an index value of 4.16 and thus ranked most. It was closely followed by the wearing of light clothe during hot period with. This adaptive behaviour has an index value of 4.06 and ranked second. Other adaptive measures in the order of their index values are full opening of the window with an index value of 4.00, the use of electric fan with an index value of 3.50. The other adaptive actions used by the respondents were the consumption of hot or cold food/drink with an index value of 3.44, opening or closing of door with an index value of 3.33 while the least ranked adaptive measure or behaviour used by the respondents was moving out of the classroom/staff room which has an index value of 2.36.

Table 4: Adaptive behaviour of the respondents in the school

| S/N | Adaptive Behaviour | 1 Not at all important | 2 Not important | 3 Sometimes important | 4 Important | 5 Very important | Weighted mean | RSI | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Full opening of window | 1 | 5 | 13 | 24 | 26 | 276 | 4.00 | 3 |
| 2 | Partial opening of windows | 5 | 13 | 32 | 16 | 2 | 201 | 2.96 | 11 |
| 3 | Opening or closing of door | 5 | 15 | 22 | 13 | 14 | 223 | 3.33 | 6 |
| 4 | Change activities level | 3 | 19 | 13 | 25 | 7 | 215 | 3.21 | 8 |
| 5 | Wearing of light clothes during hot period | 1 | 13 | 4 | 14 | 37 | 280 | 4.06 | 2 |
| 6 | Wearing of thick clothes during cold period | 3 | 4 | 7 | 20 | 35 | 287 | 4.16 | 1 |
| 7 | Use of electric fan | 1 | 14 | 19 | 18 | 16 | 238 | 3.50 | 4 |
| 8 | Use of hand fan | 2 | 22 | 24 | 13 | 6 | 200 | 3.28 | 7 |
| 9 | Use of fan and air condition | 5 | 20 | 18 | 17 | 8 | 207 | 3.04 | 9 |
| 10 | Moving out of the classroom/ staffroom | 19 | 22 | 14 | 12 | 2 | 163 | 2.36 | 13 |
| 11 | Drawing of window blinds | 15 | 25 | 14 | 10 | 4 | 167 | 2.42 | 12 |
| 12 | Consumptions of hot or cold food/drink | 5 | 7 | 22 | 21 | 13 | 234 | 3.44 | 5 |
| 13 | Use of shading and sun control devices | 4 | 19 | 21 | 15 | 6 | 195 | 3.00 | 10 |

## DISCUSSIONS

It is seen from the data presented in Tables 2 and 3 that variation in relative humidity ranged from 28.0 % to 80.3 % during the period of study. The highest humidity level was recorded before 9:00am and the lowest relative humidity level was recorded at 2:00pm. There was more room for absorption of moisture from its immediate surroundings when the air got warmer and the air mass expanded. It should be noted that even though, high humidity levels result in efficient evaporative cooling of the skin which lead to discomfort; as studies of Appah-Dankyi and Koranteng (2012) also indicated that when people are exposed to low relative humidity condition, they may develop signs of dry and irritated skin. This is attributable to the increase in evaporation rate from the skin. It is shown from findings of the study that the percentage of relative humidity in the staff room was more than that of the classroom second floor. More than 70% of relative humidity was recorded in the time that the air temperature was declining and air velocity maintained between 0.0 to 0.28m/s; but when the air temperature started to increase, the relative humidity descended. However, based on the above findings, the average humidity that the occupants were exposed to was between 28.0% to 80.3% (Tables 1 and 2).

It should be noted that respondents utilized more than one adaptive action due to their need for thermal comfort and the availability of the adaptive opportunities. The adaptive behaviour of occupants are of different forms. These are the adjustment by changes in clothing, activity level, consumption of hot or cold drinks/food and so on to make the occupants comfortable in view of the prevailing environmental conditions. It can be observed in the results that the respondents utilized these forms of adaptive behaviour. The first option of the use of personal adjustment by changes was however utilized than the use of controls and migration option. It was inferred that respondents would consider an adaptive action with a personal adjustment application first, before trying to seek for change in relation to building space with a view to reducing discomfort. The use of opening of the windows, putting on fan was related to the indoor spatial configuration. It is seen form the findings that moving out of the classroom and staffroom was not utilized by most respondents and this inferred that spatial configuration of the school offered a better alternative for comfort compared to moving out.

## CONCLUSION

The physical and locational characteristics of the building have impact on the thermal comfort of the occupants. This was seen in the influence of the passive design features of the school such as orientation, vegetation, special shading devices and materials of construction that affected the indoor thermal environment. From the objective point of view, it was seen that staff room had the lowest mean temperature (30.6$^0$C) while classroom had the highest mean temperature (31.4$^0$C). This may be as a result of little of vegetation and closeness of vegetation in the direction of staff room that served as shield to the staff room building from solar heat gain, and other school's building such as classroom that did not have much vegetation in its direction.

The results gotten during the period of the research work showed that indoor air temperature in classroom was found to be between 27.9$^0$C and 31.4$^0$C, and 27.9$^0$C and 30.4$^0$C for the staff room floor respectively; while the indoor relative humidity were found to be between 28.0% and 80.3% for the classroom floor, and 29.6% to 76.0% for the staffroom floor. Though, from the subjective assessment, it was also seen that majority (89.2%) of the occupants were satisfied with their environment even though the measurements taken exceeded the ASHRAE standard of temperature (26$^0$C to 28$^0$C) and relative humidity (30% to 70%) for dry season. The study showed that respondents in a tropical environment such as Nigeria, may have a higher heat tolerance since they show resilience to thermal conditions which exceed the standards. Also, it was noticed that there was no much differences in the thermal comfort feelings of students and teachers as 48.3% and 36.7% of the respondents (85.0%) that fell within the ASHRAE comfort range were students and teachers respectively.

Through this study, the material of construction of the secondary school, bricks, has been observed to have influence on its thermal performance and how the occupants in both staffroom and classroom adapt to the operating indoor environmental conditions. In order to aid effective learning environment for the students and the required productive level of the staff, any secondary school buildings to be constructed with bricks should be designed in such a way that its openings will be well positioned to allow cross ventilation to take place. The designers of the institution should put into consideration the effect of the good landscaping, growth of ornamentals and provision of necessary passive features that will enhance the occurrence of comfortable indoor environmental conditions. Occupants of schools should stick to any of the adaptive measures that would make the indoor environmental conditions suitable and also enhance their productivity. Further studies should be carried out in this type of school constructed with bricks, and the measurements should transverse seasons of weather and over a number of years so as to give a long term representation of the behaviour of the results

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