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Developing Architectural Model Design for Improving Indoor Thermal Comfort of Residential Buildings in Warm Humid Climate of Abia State, Nigeria

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Abstract

Thermal comfort in residential buildings situated in tropical environments such as in Nigeria, has remain an issue of concern to architects and all environmental design professionals,, while shelter remains primary need of humans because almost everything man does takes place indoors. Indoor environments should therefore provide the required microclimate. The study investigated thermal comfort in residential buildings in Abia State with an aim to developing a design model that will improve indoor thermal comfort. Three urban areas, one from each of the three geopolitical zones were selected. Umuahia, Aba, and Ohafia. Each of the urban areas was divided into 3 cells, using prominent roads. 27 residences nine from each cell were selected and 81 in all. The sample consists of 27 from each of the three income groups. These buildings were subjected to thermal comfort test between January 2009 to December 2011. Dataloggers, calibrated to read and store data of temperature and relative humidity thrice daily, literature review, questionnaires, measured drawings and interviews formed the primary data. Secondary data on outdoor climate came from Agricultural Meteorology Station, Umudike. The result revealed that 57 buildings or 70.3% deviated from comfort zone of 20 to 26 degrees Celsius. The reason for deviation was due to lack of professional input which resulted in the abuse of buildings regulations and architectural principles for thermal comfort design. Guideline for enhancing thermal performance of residential buildings in Abia State urban environments was deducted from experimental analysis and literature and model design developed, built and operated from 1st January to 31st December 2013 under the same experimental conditions, with the case study buildings. The result was positive with an average temperature of 21 degrees Celsius. The study concluded that model designs for buildings that will enhance thermal comfort in residential buildings is possible. It recommended that the guideline be made compulsory in practice and thought in all tertiary institutions, if the war against climate change and energy preservation must be won.

Keywords: *Model design, Residential building, Thermal comfort, and Warm Humid climate and Energy efficiency*

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Background to the Study

Shelter remains a basic need for man after food, and man's effort to modify this need has never weaned ever since he evicted animals from caves and made cave his first permanent home, (Antoniades, 1992). Man's desire to modify this cradle home eclipsed when he struck fire by accident, a treasure he needed not only to moderate the adverse weather conditions prevailing on him, but also to ward of predatory animals. Antoniades, (1992) also inferred that man's continuous effort to improve on his shelter is as a result of the fact that only little of his activities take place outside.

Residential buildings are buildings where people live for a long time or permanently, and where people carry out dawn to dusk activates like rest, read, sleep, and cook and eats, and answer nature's call (Akande, 2007). It is therefore a place that should provide comfort, among which are warmth and cooling,"thermal comfort". Contrary to Akande (2007), most residences in urban environments inAbia State are cells of unhappiness, because of their inability to provideindoor thermal comfort. It became necessary therefore to investigate why this discomfort situation exist against the opinion of scholars like Akande (2007), Akande and Adebamowo (2010) and Rao (2007), who asserted that residential buildings should provide the micro climate required for all human activities. The need to actualize this assertion that residential buildings should provide the microclimate required for all human activities must be underscored and as rightly pointed out by Le – Corbusier (1977), the architect remains an authority with the mandate to bring man in harmony with his environment. The principal tools in the hands of the architect in achieving this, remains design, specification and construction.

A study of architecture and indoor thermal comfort before the discovery of electricity in 16th century by Benjamin Franklin and the introduction of mechanical or artificial means of improving ventilation and lighting, reveals that man was able to provide himself the required comfort level as need demanded in his residences through amastery of his climate and appropriate use of building materials available in his locality. (Alozie,2014) . In like manner, the early Greeks , Romans and American Arizona, when hit by energy crisis in over 2500 and 1000 years ago respectively, developed ideas that enabled them overcome the situation (Botkin and Keller 1998), just like the case in Africa ,Nigeria and specifically in Igbo traditional area. Thetraditional builders were able to develop high degrees of indoor thermal comfort in their buildings (Domochowoski,1990) which is a pointer that contemporary architecture with the advantage of technology today, could supersede this feat by traditional builders, and naturally achieve thermal comfort and energy efficiency in their new buildings designs and the old ones they renovate.

Today, the need for air conditioning and other mechanically driven machines used in providing cooling , heating and lighting when and where needed in buildings have like in the ancient times become so demanding that electricity which is the main source of energy in homes, among developing nations, have become scarce (Alozie 2014). According to Zain (2004), energy is scares and expensive.The desire to improve on the indoor thermal comfort requirement and the creation of a reduction in energy consumption in residential buildings in Abia State urban environments is therefore timely, a quest furtherorchestratedby revelations in literature of civilizations that overcame similar circumstances.Furthermore this study has become needful considering the influx of people from, within and outside the state to the urban areas of Umuahia, Aba and Ohafia, according to Nigerian Population Commission NPC (2017),Abia State recorded an increase of 15% in the past five years in her urban population.

This increase has not been matched with increase in housing sector and the gap existing in the housing sector, made many landlords to create undersigned and unapproved extensions in their buildings. These attachments' causes overcrowding, making the environment slums. Slums according to Akande and Adebamowo (2010) are major causes of airborne infections which may retard productivity and efficiency in people. This paper combined experimental studiesand literature reviews to develop guidelines that will assist architects, engineers, builders, and developers in ameliorating indoor thermal discomfort in residential buildings, as well as create energy efficient buildings not only in Abia State, but in areas with similar climatic conditions.

Aim of the Study

The aim of the study is to develop architectural model design for improving indoor thermal comfort of residential buildings in warm humid urban environments of Abia State, Nigeria. In pursuit of this aim, literatures were reviewed to support experimental studies. This paper continued where Alozie, Eze, Ifebi and Nnewo (2019) stopped.

Literature Review

Thermal Comfort

Indoor thermal comfort is achieved when occupants pursue without hindranceactivates which the building is intended to (Akande and Adebamowo, 2010). Akande and Adebamowo alignwell with Dagostino (1978) who defined thermal comfort as a state of being able to carry on any activities without being either chilly or too hot. Both definitions are rightly acceptable to this study, however the study adopts definition by American Society of Heating, Refrigerating and Air condition Engineers. ASHRAE's definition because it quantified thermal comfort. ASHRAE (2004) defined thermal comfort as that express satisfaction within the thermal environment, in which at least 80% of the sedentary or slightly active persons find their environment thermally acceptable.

Increasing concerns about indoor thermal comfort present the building industry with a challenge to cut its energy consumption. In countries such as the United Kingdom and the United States of America for example, the building sector consumes 40-50% of the total available energy, (Botkin and Keller, 1998). Of this, climate control systems namely ventilation, cooling and heating can account for about 70% of the total energy use. However, this part of the energy consumption can be reduced significantly by employing passive environmental solutions instead of mechanical ones; for example, a well-designed naturally ventilated buildings can consume only a third of the energy consumed by an air conditioned buildings. Building Research Establishment, Sustainable Constructions Unit

BRESCU.(2000) while arguably providing a comparable level of comfort. This is because passive design allows buildings to adapt more appropriately to their local climates and take better advantage of natural energy resources, such as wind and thermal buoyancy, to help condition their interior environments. Furthermore, naturally ventilated buildings have potential to provide pleasant and healthier environments for the occupants compared to their mechanically ventilated counterparts. Indeed, sick buildings are almost exclusively observed in the latter, (Baker and Stemmers, 2000).

Achieving thermal comfort through passive means in warm humid climates is not always easy because it is characterized by relatively high temperatures and high humidity, which usually require cooling and dehumidification. These difficulties lead to many buildings relying completely on air-conditioning.

Climate Responsive Buildings

Climate responsive buildings are buildings whose architectural designs, construction and operational strategies, have enabled to take advantage of potentials that will unconditionally create indoor thermal comfort and effective lighting conditions with little or no energy expenditure. (Vaughn Bradshaw 2006). This refers to buildings which take advantage of prevailing climatic potentials to create acceptable indoor thermal comfort and lighting conditions (ASHRAE, 2004).

Orientation and Spatial Organization

Orientation and spatial organization affect the ability of a building to ventilate and receive solar radiation. To minimize solar gain and maximize ventilation, traditional buildings in the warm humid climates usually employ spread-out plans and permeable internal organization. according to Leaurungneong (2006) by orientating the longer sides of the buildings to intercept prevailing winds and the shorter sides to face the direction of the strongest solar radiation, effective ventilation can be achieved, while thermal impact from solar radiation is minimized, Leaurungneong (2006). Such strategy can also be applied effectively in modern buildings.

Shading

Solar gain through windows is often component of the heat gains of a building. Also solar radiation on the opaque part of the building envelope raises the surface temperature of the envelope and contributes to the heating of the interior environment. A number of investigations highlight the importance of providing effective shading as part of overall strategy for preventing overheating in warm humid climates.

Effective shading can be provided by various means, including dedicated shading devices, nearby structures, vegetation and special glasses. Generally, external shading devices are considered the most effective, since they intercept solar radiation before it passes through the building envelope into the interior space. An appropriately oriented high-pitched roof which affords self-shading and allows only one side of itself to receive direct solar radiation at a time is another possible shading technique. A key issue which should be considered in shading design is its tendency to conflict with day lightening. Reduced day light penetration due to inappropriate shading design can increase the demand for artificial lighting, which then offsets the energy savings from reduced heat gains; Such a conflict can be lessened, for example, by using interior surfaces of high reflective values, such as those in light colors, or using light shelves to reflect daylight into the deeper part of the interior; Moveable shading devices, such as louvers, which allow the occupants to adjust their local lighting and thermal environment, are another solution. When shading is provided by a special glass, the choice of glass is essential for balancing the benefit of heat gain reduction with that of day lighting.

Material, Color and Texture

Inwarm climates, materials for building envelopes and the surrounding surfaces, such as walkways and terraces, should help minimize heat gains into the buildings. Leaurungreong (2006) shows that many traditional buildings in warm humid climates use light-weight materials along with relatively permeable constructions, such as wooden walls with ventilation gaps and wooden bamboo strip flooring, to allow the interiors to cool rapidly in the evening following the outside air temperature, and achieve a relatively comfortable environment during sleep hours. Such materials often provide poor thermal insulation, and so to reduce heat gains shading is given to the area in the form of projected roofs, shutters and vegetation. However to minimize thermal impact from solar radiation, multiple layers of materials may be required to make up a building envelope. A layer of insulation, such as foam or glass fiber, is probably required to cut effectively conductive heat transfer through opaque surfaces which receive strong solar radiation, Suriakom and Srisultapan (2007). In addition, a ventilation gap may be beneficially provided between the different layers of the envelope materials to vent excessive heat accumulated within; Such a gap may also be internally lined with a reflective material, such as aluminum foil, to help block irradiative heat transfer; Pasilo et al (2007).

Furthermore, double-gazing with low-emissivity coating, more commonly found in colder climates, may be used to reduce appreciably the ingress of heat building up on the external glass surface. Thermal mass materials are probably appropriate for spaces used during daytime as they delay heat transfer into the interiors during working hours, whereas light-weight materials are more appropriate for spaces used at night, as they allow the interiors to cool down quickly during sleeping hours. Yimprayoon (2004) and Piriyasatta (1999). To prevent heat accumulating at night in well-insulated, high-mass buildings with multi-layered glazing, effective ventilation of the building's structures should be provided. Also, the color and texture of the building envelopes and the surrounding surfaces are important, in general, lighter colors and smoother surfaces lead to lower surface temperatures; Doulos et al (2004) , Khamput and Suweero (2007), and therefore are desirable from the thermal comfort point of view. Indeed, it has been shown by Givoniand Hoffman (1968) that in warm humid climates a white roof can have an average temperature which is a few degrees lower than that of the outside air, owing to its 24-hour long-wave radiant loss being greater than the net solar energy it absorbs.

In addition to the use of traditional and imported materials, a number of new materials have been developed in warm humid climates, usually from local aw materials, such as agricultural wastes. Examples include particle boards from a mixture of rice straw and rice husk, Pasilo, Hanchaiyungwa and Teebooma (2007) and grass, Leaurungrong (2006); insulation boards from cassava and corncobs; a composite concrete from a combination of durian peel, coconut fiber and coconut coir,; a brick from a combination of soil and coconut coir , a cement board from coconut coir, Asasutjerit , Hirunlabh ,and Khedari (2007), a concrete block from oil palm fibers and bagasse, Boonma (2006) and sandwich walls from rice straw and rice coconut coir, have lower thermal conductivities than those of conventional materials such as bricks and concrete, and in this regard are more appropriate for construction in warm humid climates.

Vegetation

Vegetation can be an effective means of moderating the temperature around a building and reducing the building's cooling requirement. Vegetation in the form of trees, climbers, high shrubs and pergolas, for example, can provide effective shading for the building's walls and windows. Grand cover by plants also reduces the reflected solar radiation and long-wave radiation emitted towards the building, thus reducing solar and long-wave heat gains. The evapotranspiration process also cools the ambient air and nearby surfaces.

Furthermore, climbers over the walls can reduce the wind speed next to the wall surfaces and provide thermal insulation when the exterior air temperature is greater than that of the walls. Fieldwork in warm humid climates has reported the ability of plants to lower the ambient temperature appreciably, with areas such as urban parks often found to be a few degree Celsius cooler than the surrounding built-up areas;

Also the average temperature of the building's walls which are shaded by plants can be 5-15°C less than that of unshaded ones, depending on the local climates and planting details, and Parker (1981). Likewise, a roof garden can attain temperature 10-30°C below that of an exposed roof surface, depending on the roof construction, planting details and surrounding conditions.

To compliment indoor comfort in residential buildings, quantitative planting principles should be developed which will help optimize the cooling effect of vegetation especially when it is used in conjunction with and in place of conventional shading devices and insulation. Attention should be given to balancing the benefits from temperature reduction with the adverse effects from increased humidity due to the evapotranspiration process, especially when plants are grown near ventilation inlets. Optimization of the use of local plants should also be explored.

Cooling Techniques

Even with the best effort to reduce heat gains, cooling requirement may not be eliminated. In such cases, a range of passive cooling techniques may be employed to help achieve thermal comfort. Key coiling techniques for warm humid climate involve appropriate utilization of natural ventilation, thermal mass and heat dissipation by radiation and evaporation.

Ventilate Cooling

Ventilation provides cooling by enabling convective heat transfer from a warm building's interior to a cool exterior. Also, sufficiently high indoor air velocities give the occupants direct physiological cooling.

Ventilate Cooling by Wind

This technique relies on wind force to produce pressure differences between the interior exterior of a building, which in turn lead to internal air movement and heat removal from the interior. Sufficiently high indoor air velocities can also increase appreciably convective heat transfer from the occupants' skin and clothing and the rate of skin evaporation, the net effect of which is physiological cooling. With an indoor air speed of around 1.5-2.0m/s, ventilation can provide comfort in regions and seasons when the maximum outdoor temperature does not exceed about 28-32°C, depending on the humidity level and the acclimatization of the population; Givoni (1991). Such climate conditions are common in warm climates,and work in the region shows that thermal comfort can be brought about for an appreciable part of the year at least 20% according to Tantasvasdi et al; (2001) andby allowing wind to induce sufficient indoor air movement. However, an indoor air velocity above 0.9m/s may be considered excessive for a working environment , due to it being able to disturb loose paper; Allard, (1998).

Several investigations by Tantasavasi(2001) and Srisuwarm (2001) agree that, in general, to achieve effective ventilation in warm humid climates at least two large operable windows should be provided on different walls, preferably one opposite the other, with one of them intercepting the prevailing wind. When the windows cannot be orientated to face the wind, wind deflector, which may be in the form of appropriately placed internal partitions, can be employed to channel air through the occupied zone. Tentasavasdi (2001) and Srisuwam (2001).Obstruction of the air path should be minimized. Furthermore, windows should be at the body level to increase potential for physiological cooling; Sirisuwam(2001). To complement these qualitative guidelines, qualitative design principles for maximizing the cooling effect of wind in warm humid climates are developed.

Ventilate Cooling by Buoyancy

This technique relies on temperature differences between the Exchanger, for example. This will allow the interior to be cooled below the exterior, and achieve thermal comfort when the exterior temperature is uncomfortably high. Attention should be given in particular to the resultant interior temperature structures which hold the key to the control of flow patterns and thermal comfort. Wind could also be introduced to buoyancy-driven system to promote heat removal and physiological cooling. Net flow will be reduced along with the cooling effect, however, if the wind-produced velocity exceeds the buoyancy produced velocity, the net flow will be greater, although the flow regime will be reversed following the direction of the wind, greater cooling may be expected as a consequence. Such interaction between wind and buoyancy highlights the need for locating the ventilation inlet and outlet appropriately to optimize the cooling potential of natural ventilation.

Thermal Mass

Thermal mass can be defined as a material that absorbs or releases heat from or to an interior space. It can delay heat transfer through the envelope of a building and help keep the interior cool during the day when the outside temperature is high. Moreover, when thermal mass is exposed to the interior, it absorbs heat from internal sources and dampens the amplitude of the interior temperature swing.

Thermal mass can be utilized in several ways. The mass may be integral to the building envelope to provide direct cooling, or it can be remote, such as the earth under or around a building, through which fresh air is passed and cooled before entering the occupied space. Traditionally, thermal mass is used in warm humid climates predominantly in public buildings of social and religious importance such as temples, whose heavy masonry envelopes also satisfy the need for durability. Appreciable reduction of the indoor temperature can be achieved in such buildings, with indoor air maxima about 3°C below outdoor air maxima having been observed in some cases; Srenhthaputra (2003), Srenshthraputra (2003). For modern buildings in warm humid climates, small-scale experiments; Piriyasatta (1999) and computer modeling; suggest that thermal mass can make an appropriate envelope material for spaces used primarily during the day, example living rooms, since it can help the interior cool during the occupied period. However, thermal mass is inappropriate for spaces used mainly at night, example bedrooms, as the mass usually releases hear to the interior during that period and may warm the space to an uncomfortable temperature.

To optimize the daytime cooling capacity of thermal mass, the mass should be ventilated at night to allow relatively cool night air to remove heat absorbed in the mass during the day. Such use of nocturnal ventilation in conjunction with thermal mass is more common in hot dry climates, which relatively high diurnal temperature swings and low minimum night-time temperatures. Nevertheless, computer simulations Streshthaputra (2003), Streshthaputra (2003) and Shavbiv and Capelulo (2001) suggest that this technique may also have potential; in warm humid climates where night-time temperatures are generally higher. A reduction inthe indoor temperature of about 3-6°C below the exterior air may be achievable, depending on the local climate, the amount of mass, its distribution and the ventilation details.

Methodology

The study which continued where Alozie et, al (2019) stopped share similarities in literature and methodology was conducted in the three geopolitical zones in Abia State. This was done to achieve spatiality in results, assessment and comparativeness, thus an urban area was chosen from each zone on purpose because they are the significant urban areas in each of these geopolitical zones. Umuahia was chosen from Abia Central, Aba, from Abia South and Ohafia in Abia North.

Twenty seven residences were methodological selected , nine each from low, middle and high income buildings respectively. Each urban area was divided into three cells, A, B and C using prominent roads as demarcations. Six roads were selected by balloting and on each road one each of the three income groups was selected on purpose, too after considering its passive potentials. Thus nine residences from each cell, comprising of three low incomes, three middle income and three high income buildings, this made up twenty seven buildings from each urban area, nine each from each of the income groups. The study S took place between January 2009 to December 2011. This time range is the minimum required to conduct a research of such. (Ayoade, 2006)

Data loggers were mounted at 1.5 meters in the living and sleeping areas. A bedroom most advantaged to provide thermal comfort condition was chosen in each case. The logger which took simultaneous values of temperature and humidity were mounted in the living room with a sensor that sends readings to the control logger mounted in the bedrooms. In like manner, a second logger was mounted in the veranda or under a shade to record theoutdoor temperature and humidity.

Literature, interviews, questionnaires and measured architectural drawings formed the primary data. Secondary data were collected from Agricultural Metrological Agency, AGROMETU mudike, a subsidiary of Nigeria Metrological Agency NIMET. AGROMET is in Federal Research Institute Umudike, Abia State.

The data loggers were calibrated to read off and store data every eight hours at 7.30 am at humidity peak, at 3.30 pm when the sun is at its peak and at 9.30 when cooling had set in. The thermal index used to determine the result is the Effective Thermal Index (ETI.) The index allows a temperature range of 20 to 26 degrees Cercus for comfort range also, ASHRAE (2004)'s definition which allows that 80% Of the population under examination must report that they are comfortable was used in canalizing the inmates response to ASHRAE'S seven point scale for thermal assessment among humans.

The scale ranges between3 to -3. In detail 3 is hot, 2 warm, 1 slightly warm, 0 for neutral, -1, for slightly cold, -2 for cool and -3 for cold. The Bedford scale however is simplified haven described 0 as comfortable. Bedford remarked 3 as much too warm, 2, too warm , 1 , comfortably warm, 0 as comfortable, -1 as comfortably cool, -2 as too cool and -3 asmuch too cool (Alozie, Odim and Ehibudu 2016).

Findings and Discussions

Fifty seven residences out of eighty one, representing 70.3% failed, while twenty four buildings or 29.7% passed. The buildings that failed were discovered not have followed views unveiled in literature and lacked professional involvement. According to Alozie (2014) thermal comfort in buildingsdepends not only on air movement inside and outside the building, but also on the architecture of the building. Alozie (2014) also pointed out that architecture of the building can enhance its natural ventilation, which reverses to controls its indoor temperature and relative humidity especially in warm humid climates. Alozie, (2014) underscores therefore the need for passive design. Ajibola (2001) in his submission attached the amount of radiation into the building interior as a major factor in determining indoor thermal comfort in buildings, this assertion is in alignment with Ajibola (2001), who listed passive design as a most appropriate natural tool to removing indoor thermal discomfort in buildings. Ajibola (2001) , called on environmental designers especially the architect to go back to mastering the following in design, orientation of buildings on site, windows; types, opening and location in buildings, landscaping , use of trees , grasses, shrubs which aids cooling by blocking radiation , and recommended the use of climate responsive building materials, and shading devices , fixed and movable types.

The research discovered that the 70.3% or 57 of the test buildings which deviated from the Effective Temperature Index (ETI) used for the test had the following defects which actually resulted to its failure.

Over Development of the Building Plots

Over development of the building plots and poor zoning of living and sleeping areas contributed to the failure of the buildings used in the thermal comfort. Building regulation requires that 33.3% or 1/3 of the available plot areas be built up in residential building , it was discovered that some buildings developed 65%, 70% and above. High fence walls also acted negatively on air flow. In some cases windows open very close to the fence due to inadequate setbacks.

As noted in Ogunsote (1990), building orientation is a significant design consideration when designing to achieve thermal comfort in buildings. Buildings should be oriented to benefit from the prevailing climatic conditions like the sun and the wind. It is necessary that areas like the bedrooms and the living rooms be removed from being heated from direct sunlight. Windows should be aligned to take advantage of air flow around the site.

Inadequate Building Set Backs

Building regulation demands that all buildings align with the building line. A set back of not less than 3 meters from the road or 9 meters from the center of the road is always the case. Buildings must observe a minimum of 3 meters from all close properties. The buildings with failed results did not follow this rule, which limited air circulation.

Poor Ventilation

Of all elements in the building envelope, windows and other glazed areas are most vulnerable to heat gain or losses (Ogunsote, 1990). Proper location, sizing and type of windows and shading form an important part of bioclimatic design, as they help keep the sun and wind out of the building and allow them in when needed. The buildings that failed thermal comfort test had defects in their window system.

Landscaping

Mazrina (1979), identified landscaping as important element in altering the microclimate of any building. Proper landscaping reduces direct sunshine from striking and heating up the building from the ground surfaces. In an experiment by Mazrina (1979) , it was discovered that the indoor temperature of buildings shaded by trees were 2 to 2.5 degrees Celsius lower than those un-shaded.Therefore trees, grasses and shrubs are landscape elements valuable in reducing radiation into buildings.

Thermal Mass

Thermal mass increases the indoor temperature during the night, as conventional hot air blowing through the mass empties into the building interior and heats it up. This may be good for arid climates where the night is cold and may need warming , but definitely not for warm humid climates. Concrete stores heat in the day and transmits same into buildings at night . Concrete mass is not recommended as a dominant landscape element for warm humid climates because of this. Due to limited plot sizes available for development in urban areas in Abia State, the required area is over built and this makes mass concrete the most suitable landscape element. Buildings with poor thermal performances were mostly landscaped in mass concrete.

Specifications

This a professional input and when wrongly done results. in many structural and environmental failures. Mazrina (1979) is of the opinion that the choice of building materialshelp in promoting indoor thermal comfort as building materials reduces embodied energy of buildings to attain the desired comfort conditions desirable in warm humid climates. The roof receives significantsolarradiation and plays an important role in heat gain and losses. Choice of material for finishing outside roofing sheets may affect ventilation and day lighting as well as radiation. Test buildings that did not conform to thermal index standard lacked the right specifications which were because non of the building plans was tracable to professionals.

Passive Guidelines for Achieving Thermal Comfort in the design of Residential Buildings in Warm Humid Climate of Abia State, Nigeria

The study took into considerations details of both buildings that conformed to thermal comfort index standard and those that did not. Reasons for failures and success were noted and analyzed and compared to literature. It was discovered that all buildings that did not provide acceptable indoor comfort, did not comply with passive design features raised in literature will those with acceptable results did. The study therefore under listed the following rules that if applied will lead tothe development of thermally comfortable residential buildings in the state.Engagement of building professionals, Architects andEngineers at the inception of every building as this will guarantee the following,Proper building orientation on site,(2) Proper ventilation(3) Right choice, size and location of windows, (4)Good landscaping, planting of deciduous trees, grasses and shrubs, (5) Right shading devices and right locations of each, (6) Adherence to building codes and town planning regulations, and (7) Specification of thermal friendly building materials.

Conclusion

From the findings, the above guidelines which were outlined to assist the architect, all environmental professionals, and developers realize thermal comfort in their buildings, develop energy efficient buildings was applied, the design was built and operated with high degree of success, the study thus concluded that it is possible to develop architectural design models that will enhance thermal comfort performance in residential buildings in Abia State urban environments. This will activate the realization of energy efficient buildings which will have a direct impact in energy conservation, global warming and climate change. It will reduce the importation of machines that provide electricity and their spare parts. This will mean conservation of foreign currency and increased foreign reserve. The notable noise and air pollution that accompanies these electricity generating machines will reduce and health quality improves. This will usher in the development of sustainable built environment. See appendices for model design and experimental results.

Recommendations

The study recommended that architects, engineers and estate developers apply the guidelines in order to realize sustainable residential building designs that will provide acceptable indoor thermal comfort and energy efficient in operation.

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Appendices

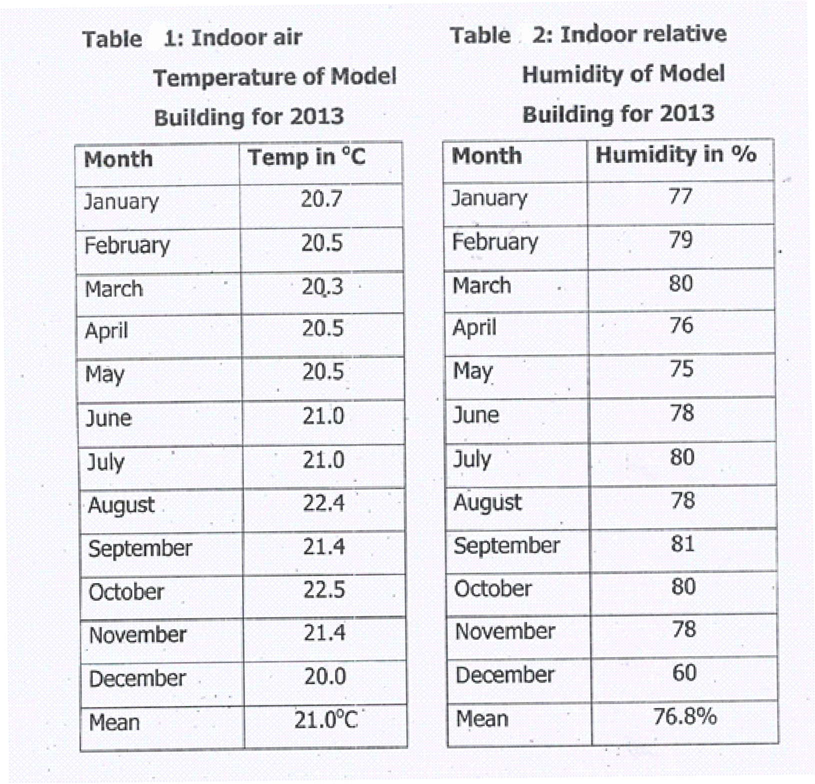


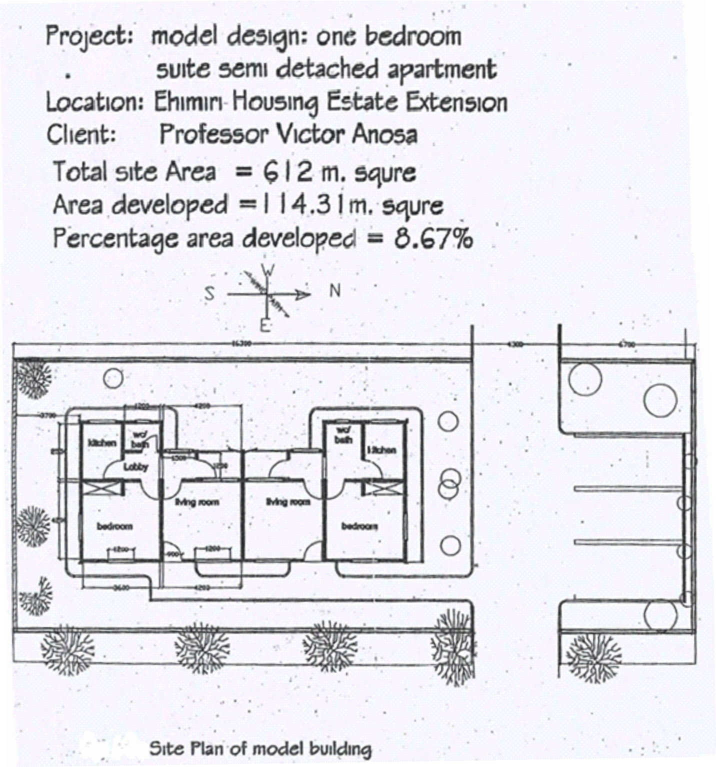
Table 1: Indoor air Temperature of Model Building for 2013

Month	Temp in °C
January	20.7
February	20.5
March	20.3
April	20.5
May	20.5
June	21.0
July	21.0
August	22.4
September	21.4
October	22.5
November	21.4
December	20.0
Mean	21.0°C

Table 2: Indoor relative Humidity of Model Building for 2013

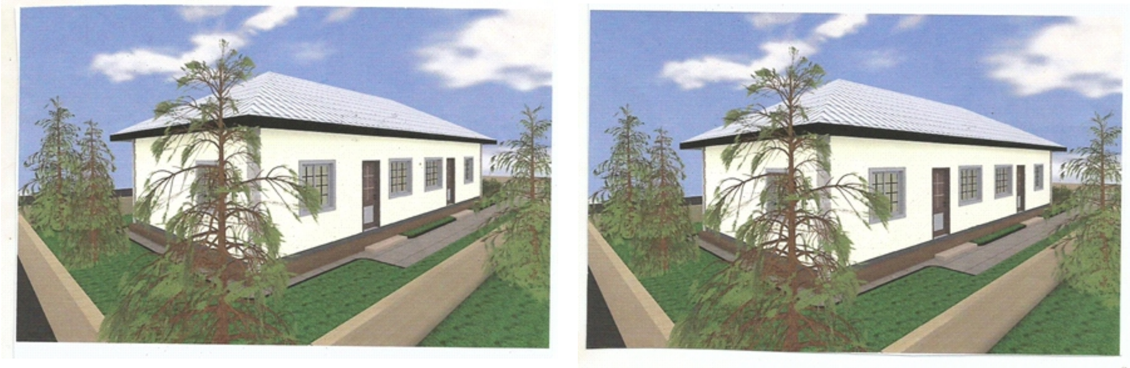
Month	Humidity in %
January	77
February	79
March	80
April	76
May	75
June	78
July	80
August	78
September	81
October	80
November	78
December	60
Mean	76.8%

Appendix 1



Appendix 2
3 Dimensional Impressions of Proposed Model Design

Appendix 3
3 Dimensional Impressions of Proposed Model Design



Appendix 4
3 Dimensional Impression of Proposed Model Design

Appendix 5
Picture of Model Building