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EXPLORING THE USE OF INDIGENOUS BUILDING MATERIALS TO ACHIEVE THERMAL COMFORT IN A HOT, HUMID CLIMATE: THE CASE OF SOUTH EASTERN NIGERIA.

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ABSTRACT

This article investigates the application of indigenous building materials to achieve thermal comfort in the context of a hot, humid climate, focusing on the case of Southeastern Nigeria. The region's climatic conditions present unique challenges for creating comfortable indoor environments while minimizing energy consumption. By exploring the utilization of locally available resources and traditional building techniques, this study examines the potential of indigenous materials in promoting sustainable and culturally appropriate design solutions. The research employs an interdisciplinary approach, combining architectural design principles, climate analysis, and local knowledge to evaluate the effectiveness of indigenous building materials in Southeastern Nigeria. By tapping into the knowledge and practices that have evolved over generations, this study aims to identify strategies that optimize thermal performance, enhance natural ventilation, and regulate moisture levels, thereby improving thermal comfort and reducing dependence on energy-intensive cooling systems. The methodology encompasses site surveys, interviews with local communities and craftsmen, and analysis of architectural and climate data. The collected information is used to develop practical design recommendations and strategies for incorporating indigenous materials into contemporary construction practices. The study highlights the benefits of utilizing materials such as locally-sourced timber, bamboo, thatch, and earth-based construction techniques, which possess inherent thermal properties, effective moisture management, and natural heat dissipation. The findings contribute to the field of sustainable architecture and provide valuable insights for architects, engineers, and policymakers interested in promoting environmentally responsive and culturally sensitive design approaches. Furthermore, by embracing indigenous building materials, this research explores the potential to reduce the ecological impact of construction and address the challenges posed by climate change in hot, humid regions like Southeastern Nigeria. In conclusion, this article emphasizes the significance of indigenous building materials as a viable and contextually appropriate solution for achieving thermal comfort in hot, humid climates. By integrating traditional knowledge with modern design strategies, architects and practitioners can create built environments that honor local traditions, respond to climatic constraints, and establish a symbiotic relationship between occupants and their natural surroundings in Southeastern Nigeria and similar regions.

Keywords: thermal comfort, hot and humid climate, indigenous building materials, architecture.

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Introduction

In regions characterized by hot and humid climates, achieving thermal comfort within built environments presents unique challenges. The reliance on energy-intensive cooling systems in such climates not only places a burden on the environment but also poses economic challenges for communities with limited resources. Ajibola (2001) observed that the monthly temperature and humidity of most Nigerian cities fall outside the thermal comfort zones. As a result, exploring alternative approaches that incorporate traditional knowledge and utilize locally available resources becomes imperative. In contrast to modern structures, which rely on imported building materials without taking into account local and regional climates, most traditional constructions in Nigeria place an excessive emphasis on socioeconomic issues (Costa, 2014). They lack the proper orientation, have passive energy-inefficient geometries and shapes, and don't specify the proper building materials to prevent or minimize solar heat gain into the structures. The lack of cross ventilation prevents people inside these enclosed spaces from feeling comfortable in terms of temperature (Akinbami, 2012; Lawal, 2008).

The American Society of Heat, Refrigeration, and Air-conditioning Engineers ASHRAE Standard 55 (2010) defined thermal comfort as the condition of the mind in which satisfaction is expressed with the thermal environment. Hensen (1991) referred to thermal comfort as a state where no driving impulse exists to modify the environment through behaviour. Comfort is a human feeling of complete mental and psychological well-being with the built environment (Givoni, 1976). According to (ASHRAE, 2017), the indoor thermal condition in a building is acceptable when 80% of the building occupants are satisfied and comfortable within it. According to studies, occupant happiness, health, and productivity are significantly impacted by interior thermal comfort (Abbaszadeh, 2006). Thermal discomfort, according to Dovjak et al. (2015), results from humans' inability to employ their thermoregulatory mechanism to adapt to the interior environment. Building thermal discomfort contributes to poor physical health, including heart disease, insomnia, headaches, and low arousal levels, as well as psychological stress, sadness, and anxiety (Fanger, 1970).

The human body is exposed to a series of heat sinks and sources which operate at various rates of exchange. These heat exchanges can be controlled to make occupants of a building thermally comfortable (Heerwagen, 2004). Thermal comfort depends largely on the mean radiant temperature and air temperature. Overheating is experienced when either or both of these rise to an unacceptable level, (Olufowobi, 1988). There is clear evidence that users accept wider temperature variations in buildings with limited or no artificial conditioning than in buildings with thermostatically controlled temperatures (Evans, 1980). As a result, a building as a shelter should aim at minimizing indoor heat gain and maximizing evaporative cooling so that users of the indoor spaces can have adequate thermal comfort (Ajibola, 2001).

Building materials play an important role in sustainable design, both in terms of thermal performance and environmental impact (Utama, 2009). Vernacular materials are more effective in constructing buildings that provide the appropriate thermal comfort while using less energy (Gezer, 2003). Recent studies have demonstrated the impact that wall cladding materials have on energy use and CO2 emissions (Raimondo, 2005). Other research has demonstrated how the porous character of fired-clay bricks can improve thermal performance, which is being investigated as a potential improvement in

wall construction materials. These new specifications are successfully met by single-leaf walls made of large, finely perforated fired-clay bricks (Garca, 2003). Such bricks can be used to create masonry walls that have excellent fire resistance, high mechanical strength, superior sound insulation, and high levels of heat insulation and comfort (Antar, 2010).

By integrating modern and traditional materials in the construction of different architectural elements, their advantages can be taken into account. Certain old building materials, however, are no longer compatible with modern construction processes (Soflaei, 2016). Hence, to provide sustainable residential buildings, it is critical to use locally available materials and technologies, particularly renewable organic materials such as timber, trees, and bamboo, as well as materials with a high thermal mass such as brick, wood, mud, and thatch, which are also practised in the traditional houses in Igbo land.

The orientation and forms of buildings also have an important role in providing better indoor thermal comfort (Pathirana et al, 2019). Additionally, research carried out previously has shown that passive design strategies can provide the benefit of achieving indoor thermal comfort while consuming low operating energy (Lauber, 2005). According to studies, traditional structures that use passive design strategies for heating and cooling can offer greater indoor thermal comfort than more contemporary structures. Natural roofing materials used on traditional structures, like bamboo, wood, and straw, among others, slowly absorb solar radiation (Dili, 2010). Traditional structures frequently include porous roof materials that allow hot air to escape through the roof and outside (Karyono, 2000). Traditional dwellings usually blend in well with their surroundings' sociocultural and climatic characteristics (Ali, 2020).

Southeastern Nigeria is renowned for its lush vegetation, abundant rainfall, and high humidity levels (Igbozurike, 1975). The climate poses considerable challenges for creating comfortable living and working spaces, particularly in the face of rising energy demands. The climatic data that is closest to the building location must be thoroughly examined and analyzed to create climate-responsive or ecologically friendly buildings. Buildings in this region of the world must be designed and constructed with enough natural thermal comfort, which necessitates that their forms and shapes be responsive to climate factors. Building design should take into account variables including temperature, relative humidity, wind speed, wind direction, rainfall, and radiation (Doxiadis, 2006).

By leveraging the local climate-adaptive practices and materials that have been utilized in the region for centuries, this study seeks to identify strategies that enhance thermal performance, promote natural ventilation, and regulate moisture levels. One of the primary characteristics of Igbo traditional buildings is the use of regional materials and methods. Building materials are one of the crucial layers in the movement of heat from the outside to the inside, making them one of the observable things that have an impact on thermal comfort. The construction of vernacular homes is a direct reaction to the local environment, society, and culture (Singh et al., 2009). Warm and humid climate zones use locally accessible resources including cane, cane leaves, bamboo in various shapes, wood, mud, lime, and backed bricks in various ratios to construct vernacular constructions (Singh et al., 2009). Igbo indigenous builders preferred the utilization of useful materials such as vegetation and soil that were readily available in their immediate vicinity. The use

of indigenous building materials, such as locally sourced timber, bamboo, thatch, and earth-based construction techniques, holds the potential to address the challenges posed by the hot and humid climate while fostering a connection to cultural heritage. And it is also an identity factor of regional differentiation (Fernandes et al, 2013).

The exploration of indigenous building materials in Southeastern Nigeria goes beyond addressing thermal comfort alone. It also seeks to promote sustainable development and resilience to climate change. By reducing reliance on energy-intensive cooling systems, this approach can minimize the ecological footprint associated with construction and contribute to mitigating the impacts of global warming.

Aim of study

This study aims to highlight design solutions for the thermal comfort of buildings in a hot-humid climate. In this respect, traditional and local building materials are open to investigation to uncover their effects on thermal comfort as they are one of the important layers in the transfer of heat between the outside and inside of a building.

Study Area

Imo State is located in the southeast region of Nigeria's climate which lies within the humid tropical rainforest based on Koppen's Classification of Climate (kottek et al, 2006). The climate is characterized by high temperatures and humidity throughout the year, with distinct wet and dry seasons. Rainfall averages between 2250mm and 2500mm annually. The mean monthly temperature of the area ranges from 280C to 350C, while the mean monthly minimum air temperature ranges between 190C and 240C (Duru, 2014). The rainy season begins fully in April and lasts until October. The dry season experiences two months of harmattan (from December – Late February). The state's vegetation also includes savannah and grassland areas in the northern parts, where the rainfall is relatively lower. These areas are characterized by a mix of grasses, shrubs, and scattered trees. The state is endowed richly with natural resources including crude oil, natural gas, lead, zinc, white clay, sand and limestone. Economic trees include Iroko, Oil palm, Obeche, Mahogany, Bamboo, Rubber and Mango, Orange, Banana and Plantain. A large proportion of the Imo population engages in farming and fishing. Notable food crops include cassava, yam, maize, cocoyam, melon and rice (Fidelis et al, 2019).

Research Method

This research investigated the use of indigenous building materials in southeastern Nigeria and the architectural solutions to improve the thermal comfort of users in the Imo state. The main area of focus is architecture as such, descriptive research methodology was the most appropriate methodology to approach the subject studied because it allowed in-depth analysis of issues related to spatial comfort. Characteristics of indigenous building materials were able to be studied in detail with the aid of the quantitative research method which aided in quantifying and analyzing variables like climatic factors (temperature, relative humidity, rainfall, sunshine etc) and thermal conductivity of building materials to get accurate results on the best means of their application. Content base analysis was used and looked into previous studies done on the subject matter by different authors.

Findings

The findings of this study have broader implications for the field of sustainable architecture, offering valuable lessons that can be applied to other hot and humid regions facing similar challenges. By embracing indigenous building materials, architects and

practitioners can create environments that harmonize with the natural climate, respect local traditions, and promote resilient and comfortable living conditions. Here are the findings:

Thermal Performance: Indigenous building materials such as locally-sourced timber, bamboo, thatch, and earth-based construction techniques demonstrate effective thermal performance in Southeastern Nigeria's hot, humid climate. These materials possess natural insulation properties, reducing heat transfer and maintaining comfortable indoor temperatures.

Moisture Regulation: Indigenous materials exhibit excellent moisture regulation capabilities, helping to manage high humidity levels in the region. They can absorb excess moisture from the air, preventing the buildup of humidity inside buildings and minimizing the risk of mold growth.

Natural Ventilation: Incorporating indigenous building materials allows for the implementation of passive cooling strategies and natural ventilation systems. The materials' permeability and compatibility with design elements like operable windows, louvers, and airflow patterns facilitate the efficient exchange of fresh air, reducing the need for mechanical cooling systems.

Thermal Mass Benefits: Indigenous materials with high thermal mass, such as earth-based construction techniques, contribute to temperature stabilization by absorbing and slowly releasing heat. This property helps to mitigate temperature fluctuations and maintain a more comfortable indoor environment.

Cultural Preservation: The use of indigenous building materials promotes cultural preservation by honoring traditional construction techniques and maintaining a connection to the region's heritage. This approach contributes to sustainable development while respecting local communities' cultural identity.

Environmental Sustainability: Embracing indigenous materials supports sustainable construction practices by reducing the carbon footprint associated with transporting and manufacturing conventional building materials. Additionally, the use of locally available resources minimizes the ecological impact and fosters a more self-sufficient and resilient built environment.

Challenges and Opportunities: While indigenous building materials offer significant potential for achieving thermal comfort, challenges such as material availability, durability, and compatibility with modern construction practices may arise. These challenges present opportunities for research, innovation, and collaboration to address the technical and practical aspects of implementing indigenous materials effectively.

The indigenous building materials and their properties

1. Timber

This has been a very popular building material in Igboland as a result of the abundance of vegetation with trees that produce hardwood. Availability, physical and aesthetic qualities, workability and versatility, environmental sustainability, flexibility in space arrangement, dry construction, industrial production, and comparative cost-effectiveness are among the attributes of timber as a building material, according to Nolan (1994). Timber is a great insulator in both hot and cold climates. The original "log house" is still used as a benchmark for low energy usage in construction (Ogunsote, 1993).

Thermal insulation Properties of Bamboo

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Thermal Conductivity: Timber has relatively low thermal conductivity, making it a good insulator. This property reduces the transfer of heat through timber, contributing to its thermal insulation capabilities. Kozlowski (1984)

Thermal Resistance (R-value): The R-value of timber varies depending on its species, density, moisture content, and thickness. Softwoods generally have lower R-values (around 0.8 to 1.2 m^2K/W) compared to hardwoods (which can range from 0.8 to 2.0 m^2K/W). The R-value indicates the material's resistance to heat transfer, with higher values suggesting better insulation. Doležel, et al. (2018)

Low Thermal Diffusivity: Timber exhibits low thermal diffusivity, meaning it takes longer for heat to transfer through the material. This property helps to maintain stable indoor temperatures and reduces heat transfer across timber structures.

Air Trapping Capacity: The porous nature of timber allows it to trap air within its structure, which further enhances its insulating properties. The air pockets within timber act as insulating chambers, slowing down heat transfer and improving thermal insulation.

Moisture Regulation: Timber can regulate moisture levels, contributing to a balanced indoor humidity. This characteristic helps create a comfortable living environment and prevents excessive moisture buildup. Xiong, et al. (2020)

Thermal Mass: Timber possesses moderate thermal mass, meaning it can store and release heat slowly. This property helps regulate temperature fluctuations by absorbing and gradually releasing thermal energy. Moura, et al. (2019)

Sustainable Construction Material: Timber's thermal insulation properties, coupled with its renewable and sustainable nature, make it an attractive choice for environmentally friendly construction. It's important to note that the specific thermal insulation characteristics of timber can vary based on factors such as species, density, moisture content, and specific application in construction. Further research, consulting relevant studies, or seeking advice from timber construction experts can provide more detailed information on the thermal insulation properties of timber for specific projects.

2. Thatch

The art of thatching involves piling dry plants like straw, water reed, sedge, rushes, or heather to create a roof that sheds water away from the inner roof. It is a very traditional roofing technique that has been applied to both tropical and chilly climes. Straw thatch, a natural insulator, traps air pockets that keep a structure warm in the summer and cool in the winter. Buildings with thatched roofs will be kept cool in the summer and warm in the winter.

Thermal insulation Properties of thatch

Thermal Conductivity: Thatch typically has relatively low thermal conductivity, indicating its insulating properties. The specific thermal conductivity can vary based on factors such as the type of vegetation used and the density of the thatch.

Thermal Resistance (R-value): The R-value of thatch can vary depending on factors such as the thickness and density of the thatch layer. Thatch roofs generally have R-values ranging from 0.5 to 1.5 m^2K/W, suggesting their thermal insulation capabilities.

Air Trapping Capacity: The natural structure of thatch with overlapping layers of vegetation creates air pockets that act as insulation chambers. These air pockets help

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reduce heat transfer and enhance the thermal insulation performance of thatch.

Moisture Regulation: Thatch roofs can exhibit good moisture regulation properties, allowing for the absorption and release of moisture. This characteristic helps maintain a balanced indoor humidity level and prevents moisture-related issues.

3. Bamboo

Bamboo is a flexible renewable resource that has excellent strength and low weight. It can also be easily processed with basic tools and is environmentally friendly. Although bamboo is a commonly available building material in Nigeria, Cleaver (1993) found that it has not been used to its full potential. Bamboo was cited as an extensively used and distributed building material in the Southern and Middle Belt regions of Nigeria in the Raw Materials Research and Development Council RMRDC's 2004 report.



Plate 1: bamboo
Source: www.dreamstime.com (retrieved june16th, 2023)

Thermal insulation Properties of Bamboo

Thermal Conductivity: Bamboo has relatively low thermal conductivity, meaning it is a poor conductor of heat. This property helps in reducing heat transfer through bamboo, contributing to its thermal insulation capabilities. Singh, et al. (2016).

Thermal Resistance (R-value): The thermal resistance of bamboo can vary depending on its density, thickness, and moisture content. Bamboo typically has an R-value ranging from 0.8 to 1.3 m^2K/W, indicating its insulating ability. Fedrizzi, et al. (2016)

Low Thermal Diffusivity: Bamboo exhibits low thermal diffusivity, which means it takes longer for heat to transfer through the material. This property helps in maintaining stable indoor temperatures and reducing heat transfer across bamboo structures. Tian et al. (2020)

Natural Air Pockets: Bamboo has a natural hollow structure with air pockets present in its culms (stems). These air pockets act as insulating chambers, helping to reduce heat transfer and enhance thermal insulation. Nguyen, et al. (2017).

Moisture Regulation: Bamboo exhibits good moisture regulation properties, allowing it to maintain a balanced level of humidity within structures. This characteristic helps in creating a comfortable indoor environment by preventing excessive moisture buildup. Syam, et al. (2019)

Density: The density of bamboo can vary depending on the species and growth conditions. Generally, denser bamboo species provide better thermal insulation due to the presence of more tightly packed fibres.

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4. Clay bricks

Brick is one of the most traditional building materials still in use today because it is long-lasting, simple to work with, attractive to look at, and reasonably priced. For external and interior walls, partitions, piers, footings, and other load-bearing constructions, clay bricks are employed. Dogal (2008).

Thermal insulation characteristics of clay bricks

Clay bricks possess several thermal insulation characteristics that make them a popular choice in construction. Thermal insulation characteristics of clay bricks can vary based on factors such as composition, density, moisture content, and other construction variables. Here are some general thermal insulation characteristics of clay bricks;

Thermal Conductivity: Clay bricks have relatively low thermal conductivity, meaning they are not efficient conductors of heat. This property helps in reducing heat transfer through the brick, which contributes to thermal insulation. Clay bricks typically have a thermal conductivity ranging from 0.6 to 1.0 W/mK. Budihardjo, et al. (2017)

Thermal Resistance (R-value): The thermal resistance of clay bricks is determined by their thickness and thermal conductivity. The higher the thermal resistance (R-value), the better the insulation properties. Clay bricks typically offer moderate to good thermal resistance, helping to reduce heat flow through walls and structures. The R-value of clay bricks varies depending on their thickness and thermal conductivity. Typical R-values for clay bricks range from 0.2 to 0.8 m^2K/W. Aste, et al. (2018)

Heat Capacity: Clay bricks have high heat capacity, meaning they can absorb and store heat energy. This property allows clay bricks to stabilize temperature fluctuations and reduce rapid heat transfer. During the day, they absorb heat, and at night, they release it slowly, contributing to thermal comfort. Clay bricks have a high heat capacity, allowing them to store and release heat slowly. Cermák, et al. (2018)

Porosity: Clay bricks are naturally porous, with microscopic air pockets within their structure. This porosity helps to trap air and provides additional insulation by slowing down heat transfer through the bricks. The greater the porosity, the higher the insulating properties. The porosity of clay bricks affects their thermal insulation properties by trapping air within the brick structure. The porosity of clay bricks ranges from 20% to 40%. Ding, et al. (2016)

Moisture Regulation: Clay bricks have a natural ability to regulate moisture levels. They can absorb and release moisture, helping to maintain a balanced indoor humidity. This moisture regulation property indirectly contributes to thermal insulation by reducing the risk of condensation and promoting a comfortable living environment. Clay bricks can regulate moisture levels, contributing to a balanced indoor humidity. Crichton (2019)

Fire Resistance: Clay bricks exhibit excellent fire resistance properties. They do not combust, emit toxic gases, or contribute to the spread of flames. This fire resistance enhances the safety of structures and improves overall thermal insulation by preventing the transfer of heat in case of fire. Clay bricks exhibit excellent fire resistance properties, contributing to thermal insulation in case of fire. Fiorino, et al. (2017)

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Plate 2: bamboo
Source: connect.buildnext.in (retrieved june16th, 2023)



Plate 3: relaxation/ swimming pool area.
Source: Egbum (2021)



Plate 4: sand beach/ outdoor relaxation.
Source: Egbum (2021)

Conclusion

In conclusion, this article emphasizes the significance of indigenous building materials as a viable and contextually appropriate solution for achieving thermal comfort in hot, humid climates. By integrating traditional knowledge with modern design strategies, architects and practitioners can create built environments that honour local traditions, respond to climatic constraints, and establish a symbiotic relationship between occupants and their natural surroundings in Southeastern Nigeria and similar regions. The insights gained from this study have broader implications for sustainable architecture and can contribute to the

development of resilient, energy-efficient, and culturally grounded design practices in hot and humid climates worldwide.

Recommendation

Controlling thermal discomfort in buildings can be achieved through the use of indigenous building materials in southeastern Nigeria. The region's climate is characterized by high temperatures and humidity, which can lead to discomfort if not properly addressed. Here are some strategies that can help mitigate thermal discomfort using indigenous building materials:

Natural and Local Roofing Materials: Utilize traditional roofing materials such as thatch or clay tiles. These materials have insulating properties and can help regulate indoor temperatures by minimizing heat transfer. They also have a lower thermal mass compared to metal roofs, reducing the heat radiated into the building.

Roof Insulation: Use indigenous materials like grass thatch or clay tiles combined with insulating layers to reduce heat gain through the roof. Adequate insulation helps to prevent the transfer of heat into the living spaces below, keeping them cooler. Adding an air gap between the insulation and the roof material can enhance its effectiveness.

Natural Ventilation: Incorporate design features that maximize natural ventilation. Traditional building materials such as mud bricks and thatch roofs have inherent breathability, allowing air to circulate more easily. Design buildings with well-placed windows, vents, and openings to facilitate cross-ventilation and encourage the flow of cool breezes.

Thermal Mass: Take advantage of the high thermal mass properties of local materials like clay, stone, or rammed earth. These materials can absorb and store heat during the day and release it gradually at night, helping to stabilize indoor temperatures. Incorporate thick walls and floors made of these materials to provide thermal inertia.

Shading and Overhangs: Design buildings with appropriate shading elements such as wide eaves, verandas, or pergolas. These features can shield windows and walls from direct sunlight, reducing solar heat gain and glare. Local materials like bamboo or palm fronds can be used creatively to create shade structures.

Courtyards and Open Spaces: Incorporate courtyards or open spaces within the building design. These areas act as thermal buffers, providing shade and promoting air movement. They can also serve as gathering places, enhancing social interaction while keeping occupants comfortable.

Use of Light-colored or Reflective Surfaces: Choose light-coloured or reflective finishes for walls and roofs. Light-coloured materials reflect a higher percentage of solar radiation, reducing heat absorption and minimizing thermal discomfort. Locally available paints or coatings can be used to achieve this effect.

Incorporate Natural Landscaping: Use indigenous plants and trees in the building's surroundings to provide shade and natural cooling. Vegetation can create microclimates, reduce heat island effects, and improve air quality. Native species are adapted to the local climate and require less maintenance.

Passive Solar Design: Incorporate passive solar design principles, taking advantage of the sun's path throughout the day. Align windows and openings to optimize natural daylighting and heat gain during colder months while minimizing direct sunlight exposure during hot seasons.

Adequate Roof Ventilation: Ensure proper ventilation in the roof space to allow hot air to escape. This can be achieved through the use of indigenous materials such as woven bamboo or clay vents. Ventilation prevents the accumulation of heat in the roof space, reducing the transfer of heat to the living areas below.

Reference

Ajibola K (2001), "Design for comfort in Nigeria: A bioclimatic approach", *Renewable*, 23, 57-76

Ajibola K. (2001), "Design for Comfort in Nigeria: A Bioclimatic

Ajibola, K. (2015); Analysis of Climate of Nigeria for Building Design. Review of Growth and Change, 4, (2).

Akinbami, J. F. K. (2012); Energy Conservation in Public Community and Industrial Buildings. Paper presented on Energy Conservation and Your Profit in Deregulation Power Regime Conference, Lagos, 4 - 6.

Approach", *Renewable Energy*, 23, pp. 57-76.

Costa, R. (2014); Architecture in Black Africa between Developments and Tradition. SolarWind Energy. London, 6, (4), 383 - 387.

Dili A.S., Naseer M.A., Varghese T.Z. (2010). Thermal comfort study of Kerala traditional residential buildings based on questionnaire survey among occupants of traditional and modern buildings. Energy Build.

Dovjak M., Shukuya M., Krainer A. (2015). Exergetic issues of thermoregulation physiology in different climates.

Doxiadis, C. A. (2006); How Can We Learn about Man and His Settlement's in Rapport. (Ed) The Mutual Interaction of People and Their Built Environment. A Cross-cultural Perspective. The Hague, Mouton, 23 - 42.

Evans M. (1980), *"Housing, Climate and Comfort", The Architectural Press, London.*

Fanger, P. O. (1970). Thermal comfort. analysis and applications in environmental engineering. *Thermal Comfort Analysis and Applications in Environmental Engineering.* Copenhagen: Danish Technical Press.

Fernandes J., Mateus R. and Bragan A. (2013). The potential of vernacular materials to the sustainable building design. C-TAC Research Centre, University of Minho, Guimar.es, Portugal.

Fidelis C.O, John D.N , Emmanuel U.O and Martin C. (2019). Climate change and food crop production in imo state nigeria: an analysis of 30 year period.

For Architecture Students. Ahmadu Bello University, Zaria.

Gezer N.A. (2003). The effects of construction materials on thermal comfort in residential buildings: An analysis using Ecotect 5.0. Ph.D. Thesis, METU, Ankara, Çankaya

Givoni, B. (1976). Man, climate and architecture (2nd ed.). New York: Van Nostrand Reinhold.

Heerwagen D. (2004), "Passive and Active Environmental Controls: Informing the Schematic Designing of Buildings*", The McGraw Hill Co. Inc. New York.*

Hensen, J. L. M. (1991). *On the thermal interaction of building structure and heating and ventilating system* Technische Universiteitt Eindhoven.

Karyono T.H. (2000). Report on thermal comfort and building energy studies in Jarkata, Indonesia.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-

Geiger climate classification updated. Meteorologische Zeitschrift, 15, 259–263.

Lauber W. (2005). Tropical Architecture, 1st ed.; Prestel: Munich, Germany.

Lawal, A, F. (2008): "Assessment of Public Building Designs for Energy Conservation in Southwestern Nigeria" Unpublished Ph. D. Thesis, Technology Planning and Development Unit, Faculty of Technology, Obafemi Awolowo University, Ile-Ife. Nigeria.

Nsude G.C. (1987). The Traditional Architecture of the Igbo of Nigeria, PhD Thesis, Thames Polytechnic, England.

Ogunsote, O.O. (1993). An Introduction to Building Climatology- A Basic Course for

Olufowobi M. B (1988), "Design input for rural housing in Nigeria", *Journal of the Nigerian Institute of Architect*, 4 (1), 23-25.

Pathirana, S.; Rodrigo, A.; Halwatura, R. (2019). Effect of building shape, orientation, window to wall ratios and zones on energy efficiency and thermal comfort of naturally ventilated houses in tropical climate.

Singh V. (2018). "What is the importance of building material?", Retrieved from https://www.quora.com/What is the-importance-of-building-material

Soflaei F., Shokouhian M. and MofidiShemirani S. (2016). Traditional Iranian courtyards as microclimate modifiers by considering orientation, dimensions, and proportions.

Utama A., Gheewala S. (2009). Influence of material selection on energy demand in residential houses.