Thermal Properties of Some Local Building Materials in Nigeria: A Case Study of Ibadan

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ABSTRACT

The thermal properties of building materials have great influence on indoor thermal comfort, energy efficiency and urban thermal environment in tropics. In Nigeria, the rising use of conventional building materials with low thermal performance is a source of concern on heat retention and occupants' comfort. The thermal potentials of available locally sourced building materials are underexplored. This work comparatively studied the thermal properties of some selected local building materials commonly found in Nigeria using Ibadan as a case study. The research design used was qualitative and based on comparative literature to synthesize evidence on key thermal properties like thermal conductivity, specific heat capacity, thermal mass, thermal diffusivity, and surface characteristics. The results of the review indicate that the thermal conductivity of terrestrial materials, laterite and adobe, is lower than that of conventional sandcrete blocks, but their thermal mass is higher. This leads to a higher barrier to heat transfer and better thermal efficiency of the structure, which is useful in tropical climates. Moreover, results indicate that it is possible to mitigate urban heat through the optimal urban albedo and to enhance the thermal comfort of outdoor spaces by selecting the appropriate material. The study concludes that increased use of climate responsive local building materials may improve thermal resilience in Nigerian cities. Recommendations are made for the inclusion of thermal performance criteria in the design and regulation of buildings, for encouraging the use of stabilized earth-based materials and for undertaking field studies to verify the thermal performance of local materials under tropical conditions.

Keywords: Local building materials, Nigeria, Thermal conductivity, Thermal mass, Thermal properties.

INTRODUCTION

Background of the Study

The rapid growth of cities and population in urban areas of Nigeria has greatly altered the thermal characteristics of the built environment. Major cities such as Lagos, Abuja, Ibadan, Port Harcourt, Akure and Onitsha have seen major change in land use in the last few decades. These changes have replaced the natural plant life and water-absorbing surfaces with dense buildings, paved roads and other surfaces that do not permit water to pass through them. Most studies have focused on adaptation and sustainable living as a means of reducing the impact of climate. Thee growing effects of climate in recent years show the need for building design and construction to work with natural systems (Taiwo et al, 2025).

These changes have enhanced the Urban Heat Island (UHI) effect, whereby urban areas are continuously warmer in terms of air and surface temperatures than the surrounding rural areas. The effects of the increase in urban heat are most keenly felt in tropical countries like Nigeria where high temperatures and humidity are the norm. This has a significant impact on outdoor comfort, indoor conditions, public health and overall urban liveability (Xu et al., 2016).

Empirical data and climate records from cities such as Lagos and Ibadan show that night time temperatures are increasing and the cooling effect at night is decreasing with more frequent heat-stress conditions, especially in the dry season. These trends are linked to very compact urban structures, limited green space and the use of materials that absorb and retain a lot of heat. Consequently, buildings and urban surfaces act as heat reservoirs during the day and release stored heat at night, keeping urban temperatures elevated within the canopy layer (Krayenhoff & Voogt, 2010).

Thermal behaviour of building materials is a key but often neglected factor in urban overheating in Nigerian cities. The materials used in walls, roofs and pavements have a direct impact on the absorption, storage and re-emission of solar radiation into the urban atmosphere. Thermal properties such as thermal conductivity, specific heat capacity and thermal diffusivity determine the speed of heat transfer through building envelopes. Absorptivity and reflectivity of the surface parameters directly influence the energy absorbed or reflected by the incoming solar radiation. These properties are all related to the thermal performance of single buildings, but they also have a significant impact on the surrounding microclimate (Salata et al., 2015).

Urban albedo, the ratio of reflected solar radiation on urban surfaces, has emerged as a critical parameter in urban climate research and heat mitigation methods. High-albedo materials, sometimes known as “cool materials,” have been promoted worldwide as a way to lower surface temperatures and reduce the need for indoor cooling. Research has demonstrated that the increase of albedo in urban settings can result in quantifiable lowering of air temperature at daily and yearly time-scales (Krayenhoff & Voogt, 2010; Taha et al., 1992). However recent studies also show that the benefits of high albedo materials are local condition dependent. High surface reflectivity in densely populated urban areas may increase the average radiant temperature at the pedestrian level, resulting in increased thermal discomfort and potentially negating the desired cooling effects (Tyagi & Danish, 2025; Ghoniem et al., 2025).

Presently, the Nigerian urban development is dominated by the use of imported and industrialised building materials such as sandcrete blocks, reinforced concrete and corrugated metal roofing. These materials are often selected for their low cost, availability and fast Construction time, with little consideration to their thermal behaviour in the humid tropical climate. In contrast, traditional and native materials such as laterite blocks, adobe, fired clay bricks and timber have been adapted to the local environment and have been evolved over the years in respect to climate, availability of resources and native construction techniques. Many of these materials also have advantageous thermal properties, including high thermal mass and low heat transfer, which can help improve indoor comfort and reduce the need for mechanical cooling systems (Salata et al., 2015).

The rising cost of imported building materials in Nigeria is engendering a form of housing insecurity that could threaten the sustainability of past development efforts. Therefore, there is a growing interest in the use of locally available natural materials to guaranty affordability and sustainability. Thus, traditional roofing materials that can be produced locally in Nigeria are converted into useful building materials from agro-wastes or byproducts. Examples are wheat straw, rice straw, groundnut shells, cotton stalks, coconut husks etc. For example, coconut husks are durable and are used to produce insulation boards and roofing sheets (Olutoge & Obakin, 2017; Obakin, 2020). Although there is a growing body of global research on urban albedo and thermal comfort, there are few studies that comprehensively investigate the interaction of local building materials and urban albedo in Nigerian cities. Much of the existing research is from temperate, Mediterranean or arid regions which may not be directly applicable to the humid tropical conditions found in West Africa (Ghoniem et al., 2007). Hence, it is important to translate global outcomes to the Nigerian setting and to revisit the potential of local building materials as part of heat mitigation approaches in the region**.**

Statement of the Problem

Rapid urban growth, poor land use planning and extensive use of non-thermally efficient construction materials have led to increasing urban temperatures in Nigerian cities. The compact building designs, large swathes of asphalt and limited vegetation have all contributed to increased urban heat, especially within low- and middle-income communities where the ability to adapt is limited. These conditions increase thermal discomfort, exacerbate the need for cooling and constitute serious threats to public health especially for

vulnerable populations.

Although there is growing evidence linking the choice of materials to urban thermal conditions, construction practices in Nigeria are still characterized by the use of conventional materials such as sandcrete blocks and metal roofing with little consideration for their thermal implications. These materials tend to have high solar absorptance and low thermal resistance resulting in rapid heat gain during the day and high indoor temperatures. The response is to try and use high albedo or reflective materials as a general solution. Often, these strategies are implemented without considering the urban density, street configuration, or pedestrian exposure, in absence of proper planning, resulting in increased radiant temperatures and decreased outdoor comfort (Tyagi & Danish, 2025).

A second challenge is that traditional and local building materials are excluded from formal construction and policy frameworks. Laterite, adobe and fired clay bricks have shown good thermal performance in similar climates, but are often considered as outdated or inappropriate for modern urban development. Thermal data is rarely integrated into material selection in building policies and professional practices, leading to the frequent inconsistency and sometimes contradiction of policies and practices for managing heat in cities in Nigeria.

This highlights a key knowledge gap: there is a lack of detailed, context-specific understanding of how the thermal properties of local materials interact with urban albedo to affect microclimatic conditions in Nigerian cities. Without this understanding, heat mitigation methods may remain ineffective, superficial or even harmful, undermining efforts toward sustainable and climate-responsive urban growth.

Aim and Objectives of the Study

Aim

The aim of this study is to compare the thermal properties of some indigenous building materials in Nigeria, using Ibadan as a case study, and to analyze their implications for thermal comfort, energy efficiency, and climate-sensitive building design.

Objectives

The specific objectives of the study are to:

1. Identify the local building materials used in Nigeria and their thermal properties.

2. Compare the thermal properties of selected local building materials with those of commonly used conventional construction materials.

3. Assess the effect of the thermal properties of these materials for indoor thermal comfort and building energy performance in Ibadan.

4. Examine the possibility of thermal performance of some local building materials in supporting climate responsive building design and sustainable urban development in Nigeria.

Research Questions

The study seeks to answer the following research questions:

1. What are the major local building materials used in Nigeria, and what are their thermal properties?
2. How do the thermal properties of selected local building materials compare with those of commonly used conventional construction materials?
3. What are the implications of the thermal properties of selected local building materials for indoor comfort and building energy performance in Ibadan?
4. How can the selected building materials contribute to climate-responsive design and sustainable urban development in Nigeria?

Significance of the Study

The study contributes to discussions about architectural and urban climate issues by emphasizing the necessity of using local building materials to tackle urban heat challenges. The research provides insight for architects, urban planners and legislators to find climate responsive design solutions, in terms of the relation of the thermal properties of materials and urban albedo. The results also contribute to sustainable development goals by enabling the selection of context-sensitive materials that can improve thermal comfort, reduce energy consumption and enhance urban livability in Nigerian and West African cities.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The theoretical and conceptual bases of the study are presented in this chapter. It outlines the main concepts behind the thermal properties of building materials, urban albedo and the Urban Heat Island (UHI) phenomenon, and the links between the properties of the materials and the surface energy balance and urban thermal conditions. The chapter also situates the study within existing theories of urban climate and building physics, so as to provide a framework for analyzing the implications of local building materials for urban heat mitigation in Nigerian cities

Thermal Properties of Building Materials

The thermal behavior of building materials is important for indoor thermal comfort and for the urban microclimate around buildings. The thermal properties of a material describe how it reacts to heat transfer and energy storage and how quickly buildings will gain, store and release heat.

Thermal Conductivity

Thermal conductivity is the ability of a material to conduct heat through its mass. Building envelopes of materials with high thermal conductivity such as concrete and metal roofing sheets which are common in Nigerian cities allow for rapid heat transfer through building envelopes. This often results in increased indoor temperature during hot periods. Conversely, materials with low thermal conductivity like laterite blocks, adobe and timber impede heat transfer and can bring about better indoor thermal comfort in tropical climates.

Specific Heat Capacity and Thermal Mass

Specific heat capacity of a material is the amount of heat energy required to raise the temperature of that material by a specific amount. Material with high thermal mass has high heat capacity that lets the material absorb heat during the day and release it at night. Common building materials such as earth-based construction and fired clay bricks usually have high thermal mass that can be used to buffer indoor temperature fluctuations when designed and ventilated properly (Salata et al., 2015). However, in the dense Nigerian urban settings, the city scale excessive heat storage can also contribute to nocturnal warming which emphasizes the need to evaluate thermal mass in a larger urban context (Krayenhoff & Voogt, 2010).

Thermal Diffusivity

Thermal diffusivity is a measure of the rate of heat propagation in a material and depends on thermal conductivity, density and heat capacity. Materials with low thermal diffusivity hinder the penetration of heat which is a good feature in tropical climates, where the reduction of heat gain during the daytime is the priority. Moreover, the diffusivity characteristics of local building materials in Nigeria tend to be better than those of lightweight industrial materials. This further buttresses the potential of local materials in climate responsive design.

Surface Properties and Urban Albedo

Besides bulk thermal properties, surface properties are important for controlling the interaction between buildings and solar radiation.

Solar Absorptivity and Emissivity

Solar absorptivity is the fraction of the incident solar radiation absorbed by a surface and emissivity is the ability of a surface to emit the absorbed heat as long-wave radiation. The dark colored surfaces and untreated roofing sheets commonly found in Nigerian cities have high absorptivity, resulting in high surface temperatures and enhanced heat transfer to the surrounding air. High-emissivity surfaces can assist in cooling down at night, but the effectiveness depends on the degree of exposure to the sky and the shape of the urban area.

Reflectivity and Albedo

Reflectivity is the proportion of solar radiation reflected by a surface, and when considered at the urban scale, it is expressed as urban albedo. Urban albedo is influenced by the combined reflectance of roofs, walls, pavements and open spaces. Increasing urban albedo has been widely proposed as a strategy for reducing surface and air temperatures by limiting solar heat absorption (Taha et al., 1992).

Urban Albedo and Surface Energy Balance

Urban albedo plays a central role in the surface energy balance of cities. The urban surface energy balance describes how incoming solar radiation is partitioned into reflected energy, sensible heat, latent heat and heat storage within urban materials. An increase in albedo generally reduces net radiation and sensible heat flux, contributing to lower daytime air temperatures.

Empirical and modelling studies have shown that albedo modification can lead to measurable reductions in near-surface air temperature at daily to annual timescales (Krayenhoff & Voogt, 2010). The effects vary with climate and urban form; in particular, surface reflectivity should be assessed alongside shading and the potential for reflected radiation to affect pedestrian-level thermal comfort (Ghoniem et al., 2025).

Urban Heat Island and Thermal Comfort

Urban Heat Island Theory

The Urban Heat Island (UHI) phenomenon is defined as the temperature difference between urban areas and their rural environment. The UHI formation is caused by a variety of factors, such as the properties of surface materials, urban geometry, less vegetation and anthropogenic heat emissions. In tropical cities such as Nigeria, high humidity and limited cooling during night time increase UHI effects.

Comparative studies across different climatic regions indicate that the magnitude and characteristics of the Urban Heat Island (UHI) phenomenon differ between humid and arid environments. This variation stresses the importance of climate-sensitive material selection and urban design (Ghoniem et al., 2007). The study of urban albedo and its effect on local climate should be within the climatic context of Nigerian cities, and not extrapolating the results from temperate regions.

Urban Albedo, Thermal Comfort and Pedestrian Experience

Thermal comfort in urban outdoor spaces is affected by more than just the air temperature. It also depends on the mean radiant temperature, wind speed and humidity. High-albedo surfaces can reduce air temperatures, but can increase pedestrian radiant heat exposure. In recent research, it has been pointed out the importance of balancing albedo variations with the design of shading, vegetation and the urban environment to effectively improve outdoor thermal comfort (Ghoniem et al., 2025; Salvati & Kolokotroni, 2020).

In Nigerian cities, where pedestrian activities and outdoor spaces are heavily used, neglecting the effects of albedo modifications at the pedestrian level could be harmful to the overall quality of urban life. This demonstrates the need for design methods that integrate the choice of materials with the city's structure and its landscaping elements.

Conceptual Framework for the Study

Based on the reviewed theories, this study adopts a conceptual framework that links the thermal properties of building materials and surface albedo to urban microclimate and thermal comfort outcomes. The framework proposes that material thermal properties (conductivity, heat capacity and diffusivity) and surface characteristics (absorptivity and reflectivity) jointly influence heat storage, surface temperature and radiation exchange. These processes affect urban air temperature, mean radiant temperature and, ultimately, indoor and outdoor thermal comfort.

The framework emphasizes the significance of urban form, vegetation and climate in the Nigerian context. It suggests that the most effective urban heat mitigation techniques may have to go beyond the use of high-albedo materials to include the use of local building materials with appropriate albedo levels, shading and green infrastructure. The conceptual framework guides the analysis and discussion in the following chapters.

RESEARCH METHODOLOGY

This study presents the methodological approach adopted for the study and integrates a critical, method-oriented review of existing literature relevant to the thermal properties of building materials and urban albedo. Given the exploratory and theoretical nature of the research, the chapter combines methodological justification with an analytical synthesis of prior studies to explain how knowledge on material thermal performance and albedo-based heat mitigation has been generated, interpreted, and applied across different climatic contexts. Emphasis is placed on the relevance and adaptability of these methods and findings to Nigerian cities and the wider West African region.

Research Design

The research design is conceptual, qualitative and comparative literature based where the main purpose is to synthesize existing empirical and theoretical knowledge, question methodological approaches used in previous research and identify gaps rather than to generate primary field data.

The research design is based on the principles of building physics, urban climate science and thermal comfort studies. This allows an interdisciplinary approach to the examination of the combined effect of building material thermal properties and urban surface albedo on urban microclimate and thermal comfort.

Scope of the Study

This study is geographically focused on Nigerian cities, reflecting their climatic conditions, material culture and urban development patterns. While the primary analysis is Nigeria-based, references are made to other West African cities where climatic and socio-environmental conditions are comparable. In order to analyse thermal characteristics and urban albedo impacts, the study uses a conceptual and literature-based method that draws on previous empirical and simulation-based research. Such an approach does not require primary field measurements but paves the way for future empirical studies.

Literature Search Strategy and Selection Criteria

A literature search was conducted using Google Scholar, Scopus, Web of Science, and ScienceDirect to identify publications relevant to building-material thermal properties, urban albedo, urban heat islands, thermal comfort, and climate-responsive design. Recent academic literature was prioritised, while earlier publications were retained where they provided important theoretical foundations or directly relevant empirical evidence. No fixed publication-year cut-off is reported for this review.

Search terms were used individually and in combinations, including ‘thermal properties of building materials’, ‘thermal conductivity of laterite’, ‘thermal properties of adobe bricks’, ‘fired clay brick thermal properties’, ‘sandcrete block thermal performance’, ‘urban albedo and heat mitigation’, ‘urban heat island in tropical cities’, and ‘thermal comfort in Nigeria’. Reference lists of relevant publications were also considered to

identify additional studies.

Publications were considered for inclusion when they addressed one or more of the study themes, came from peer-reviewed journals or credible research institutions, and provided a sufficiently clear account of their data or analytical approach. Studies reporting laboratory measurements, field observations, numerical simulations, or analytical assessments were considered where relevant. Research from tropical, humid, hot, or otherwise climatically comparable settings was prioritised for contextual interpretation, while studies from other regions were used as theoretical or comparative evidence rather than assumed to represent conditions in Ibadan.

The selected literature was examined comparatively and thematically. For laterite, adobe, fired clay bricks, and sandcrete blocks, the analysis sought values for thermal conductivity, specific heat capacity, density, and thermal diffusivity. Where a study did not report a parameter, the value was not inferred unless it could be calculated transparently from reported properties using the relationship $\alpha = k/(\rho c_p)$. Calculated values are identified as such, and differences in material composition, moisture content, sample preparation, wall thickness, and testing conditions are considered when interpreting comparisons.

The review is based on secondary sources and did not involve original field measurements, laboratory tests, or numerical simulations in Ibadan. The proposed urban-zone framework and albedo scenarios are therefore interpretations developed from the literature, not experimentally validated outcomes. Search dates and the number of records identified, screened, or retained are not reported in the source records available for this revision and have not been estimated.

Case Study Selection: Ibadan, Nigeria

Ibadan Metropolis, Oyo State, Nigeria, is used as the contextual case study for discussing relationships among building-material thermal properties, urban heating, and surface albedo. Ibadan was chosen as a representative of the fast-growing tropical cities in West Africa where rapid urban expansion, changing building materials and declining urban vegetation have had a major impact on the urban thermal environment (Adelekan, 2023; Oyinloye & Popoola, 2021).

Ibadan is located between Latitude 7°15′N – 7°30′N and Longitude 3°45′E– 4°00′E, about 145km northeast of Lagos. It is the capital city of Oyo State, with an estimated land area of about 3,080 km², making it one of the largest indigenous cities in tropical Africa. Ibadan is a major metropolitan centre experiencing continued outward expansion associated with population growth and urban development. A population estimate should be accompanied by a specific official source, reference year, and geographic definition before submission.

Theoretically, the synthesis is based on Ibadan as its primary contextual reference. The choice of Ibadan was based on three criteria:

1. **Morphological Diversity:** The contrast between the high-density indigenous nucleus (e.g. Bere, Oja'ba) and the planned modern extensions (Akala Express, Bodija) provides a comparative study of traditional and modern material performance.
2. **Climatic Representativeness:** The thermal problems of Ibadan are representative of the wider West African sub-region, as it is a tropical wet-and-dry climate (in the Köppen classification).
3. **The "Brown Roof" Phenomenon:** Ibadan presents an interesting opportunity to investigate the long-term albedo drop of metal roofing and its effect on the Urban Heat Island (UHI).

Comparative Context of Ibadan within Nigerian and West African Cities

To interpret Ibadan's thermal characteristics within the wider Nigerian experience, this section compares the city's context with selected climatic and urban settings elsewhere in Nigeria. Similar to many fast-growing cities in sub-Saharan Africa, the city of Ibadan has undergone drastic land use and building construction changes leading to greater impervious surfaces, less vegetation cover and increased urban heating (Santamouris, 2015; Ziaeemehr et al., 2023).

Compared with Lagos, where urban heating is intensified by dense high-rise developments and coastal humidity, Ibadan exhibits a more heterogeneous urban morphology characterized by the coexistence of traditional neighbourhoods and modern suburban developments (Adelekan, 2023). Conversely, northern cities such as Kano and Maiduguri have higher ambient temperatures owing to their semi-arid climatic conditions. But this is also due to the same dependence on concrete and sandcrete construction, which leads to more heat build-up (Yang et al., 2025). Jos however is located on the Jos Plateau and is cooler in temperature, thanks to its higher altitude. This demonstrates that the thermal behavior of urban areas is influenced by local climatic conditions and topography when the same building materials are used (NiMet, 2023).

Ibadan, however, remains a special case study because it offers a unique mixture of traditional earth-based architecture, growing modern residential areas and diverse urban forms, allowing comparison of indigenous and modern building materials within one metropolitan area. Such diversity is a suitable background to explore the impact of differences in thermal properties of materials and surface reflectivity on urban heating and outdoor thermal comfort in tropical cities.

Table 3.1: Comparative Characteristics of Selected Tropical Nigeria Cities

City	Climatic Zone	Dominant Characteristics	Implications for Urban Heating
Ibadan	Tropical Wet-and-Dry (Guinea Savannah)	Mixed traditional and modern urban development; seasonal rainfall; rapid urbanization	Primary case study examining the relationship between local building materials, urban albedo, and urban heating
Lagos	Coastal Humid	Dense urban development; high humidity; extensive paved surfaces	Potential thermal discomfort associated with humidity and urban heat
Kano	Sudan Savannah	High solar radiation; prolonged dry season; sparse vegetation	Increased daytime heat gain and cooling requirements
Maiduguri	Sahel Savannah	Extreme temperatures; low rainfall; arid environment	High thermal stress requiring heat-resistant construction materials
Jos	Highland Climate	Higher elevation; moderate temperatures; cooler climate	Demonstrates the influence of altitude on urban thermal behaviour

Source: Author's compilation (2026)

Quantitative Comparison of Selected Thermal Properties

A quantitative comparison was compiled from studies that reported material properties. The sources differ in geography, material formulation, moisture condition, and test method; the values below should therefore be read as reference points rather than a controlled head-to-head experiment. "Not reported" means that the cited source did not provide the parameter in the accessible report. For calculated thermal diffusivity, $\alpha = k/(\rho c_p)$ was applied to reported conductivity, density, and specific heat capacity values.

Table 3.2: Comparative thermal properties reported for selected building materials

Material / study context	Thermal conductivity, k (W/m·K)	Specific heat capacity, cp (J/kg·K)	Density, ρ (kg/m³)	Thermal diffusivity, α (mm²/s)	Source / interpretation
Lateritic blocks (three quarries; Burkina Faso)	< 0.60	Not reported	Not reported	< 0.30	Ouédraogo et al. (2018); reported upper limits, not single values.
Adobe bricks (Gashua,	0.185–0.428 (across two	Not reported as mass-specific cp; volumetric	Not reported	0.168–0.294	Ngaram (2020) and Adegoke (2021);

Nigeria; 5–20% moisture)	studies)	heat capacity: 1.89–2.67 MJ/m³·K	in the abstract		values vary with moisture content.
Fired clay block masonry (model input)	0.42	876	1,575	0.304 (calculated)	Reismüller et al. (2023); model input, not a Nigerian laboratory test.
Sandcrete block, 150 mm thick	0.481	920	1,900	0.275 (calculated)	Bashir et al. (2021); compiled property values; diffusivity calculated here.
Sandcrete block, 230 mm thick	0.481	920	1,950	0.268 (calculated)	Bashir et al. (2021); compiled property values; diffusivity calculated here.

Source: Author's compilation (2026)

Note. Thermal diffusivity values are expressed in mm²/s. Values marked "calculated" were computed using $\alpha = k/(\rho cp)$, with consistent units. Material composition, moisture, porosity, test method and source context differ, so the values are not directly interchangeable. These are literature values, not measurements from Ibadan. The fired-clay values are model inputs; the sandcrete values are compiled in a simulation paper from cited sources.

Assessment of Outdoor Thermal Comfort

Several studies reviewed adopt thermal comfort indices which include Physiological Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI), and Mean Radiant Temperature (Tmrt) in order to evaluate pedestrian-level thermal conditions. These methodological tools move beyond air temperature as a sole indicator of thermal performance. Reflective surfaces can reduce solar energy absorbed by building exteriors, but outdoor thermal comfort cannot be inferred from surface temperature alone. Air temperature, mean radiant temperature, wind, humidity, shading, and reflected radiation also matter. A study of surface-material albedo scenarios and shading in a hot-arid setting highlights the value of evaluating these factors together (Ghoniem et al., 2025). Its results provide methodological context, not direct evidence of outcomes in Ibadan.

Urban Form, Climate, and Material Interaction

Comparative methodological studies emphasize that the effectiveness of material- and albedo-based heat mitigation strategies is highly climate-dependent. Through a comparative study of humid tropical and arid cities, Ghoniem et al. (2007) show how the interaction between material thermal properties and urban form is influenced by climatic conditions. These studies emphasize the necessity of context-specific analytical frameworks, as strategies that may work in arid environments may not be transferrable to humid tropical cities such as those in Nigeria. The integrated approaches, which combine the choice of materials, moderate levels of albedo, vegetation and urban morphology, are systematically more effective than isolated interventions.

Conceptual Framework Application

The conceptual framework developed in Chapter Two guides the analysis by positioning local building materials as active components of the urban energy balance. Material properties influence heat absorption, storage, and release, which in turn affect urban air temperature, mean radiant temperature, and both indoor and outdoor thermal comfort.

Urban albedo is treated as a mediating variable rather than a standalone solution. The framework recognizes that optimal thermal performance in Nigerian cities is more likely to result from a balanced integration of local materials, moderate reflectivity, shading strategies, and vegetation.

Methodological Limitations and Ethical Considerations

This study relies on secondary literature, and the reviewed studies differ in material composition, sample preparation, moisture condition, test method, and reporting practice. These differences constrain direct comparison across studies. Because no original field measurements, laboratory tests, or numerical simulations were undertaken for Ibadan, the study cannot quantify site-specific temperature reductions or establish a locally optimal material or albedo value. The findings are therefore interpreted as a comparative synthesis and conceptual framework. The literature cited in the manuscript is acknowledged in-text and in the reference list; the references and numerical claims should be checked against the original publications before submission.

Although Ibadan provides the contextual focus, this review does not generate new local microclimatic measurements. Published data from other locations are used only where they provide relevant comparative or theoretical evidence, and their applicability to Ibadan is qualified.

Analytical Approaches to Urban Albedo and Microclimate

Research on urban albedo generally relies on surface energy balance analysis, remote sensing, and microclimatic modeling to quantify the effect of surface reflectivity on urban temperatures. Taha, Sailor and Akbari (1992) pioneered work demonstrating that increasing the albedo of roofs and pavements can reduce surface and indoor temperatures and cooling energy demands in hot climates.

A critical methodological insight for Ibadan is the "Aging Effect." While theoretical albedo values for galvanized steel are high (0.60), the rusted "brown roofs" characteristic of Ibadan's skyline likely possess a significantly lower albedo (0.15–0.25). This study interprets existing literature on "aged materials" to hypothesize that the core of Ibadan behaves thermally more like an asphalt desert than a reflective urban surface.

Studies have extended albedo analysis to neighbourhood and city scales. Krayenhoff and Voogt (2010) and Xu et al. (2016) examined how albedo modification can affect near-surface air temperature and broader climate or energy-system outcomes. The magnitude and direction of effects depend on the local setting; consequently, reflective interventions should be assessed with shading, street geometry, and pedestrian thermal comfort in mind (Ghoniem et al., 2025).

Table 3.3: Typical Albedo Values and Thermal Characteristics of Common Urban Surface Materials

Surface / Material	Typical Albedo Range	Urban Application	Thermal Implication
Dark metal roofing	0.10–0.25	Residential roofs	High heat absorption
Painted concrete roof (light color)	0.40–0.60	Urban buildings	Reduced surface temperature
Exposed laterite wall	0.30–0.45	Traditional housing	Moderate reflectivity
Cement-rendered wall (light)	0.50–0.65	Modern buildings	Lower solar absorption
Asphalt pavement	0.05–0.15	Roads	Major heat storage
Concrete pavement	0.30–0.50	Walkways	Moderate heat mitigation

Source: Author's compilation (2026)

RESULTS AND DISCUSSION

The findings to discuss the implications of thermal properties of local building materials for Nigerian cities, using **Ibadan** being the largest traditional city in West Africa as a primary case study. Ibadan's unique urban morphology, characterized by a transition from a high-density "indigenous" core to modern planned

peripheries, provides a rich landscape to examine how material transitions affect the Urban Heat Island (UHI). The discussion interprets key themes, highlights context-specific implications and critically examines how global findings translate to the Nigerian and wider West African urban environment.

Comparative Thermal Properties of Selected Materials

Experimental measurements, simulations and comparative analysis are used in a large part of the reviewed literature to evaluate the thermal performance of materials in urban environments. The results consistently show that the common construction materials used in urban areas such as reinforced concrete, sandcrete blocks and metal roofing sheets have high thermal conductivity and solar absorptivity, which lead to rapid heat gain and high indoor temperature in hot climates (Taha et al., 1992).

In contrast, studies on traditional and earth-based materials such as adobe, laterite, and fired clay bricks highlight their higher thermal mass and lower thermal diffusivity. These properties allow to attenuate the indoor temperature fluctuations, especially in combination with passive ventilation strategies (Salata et al., 2015). The majority of this evidence is drawn from the Mediterranean or arid zones, but the approaches employed provide a useful analytical basis for assessing the performance of materials in Nigerian cities, although with the need for appropriate climatic contextualization.

Table 4.1: Common Building Materials Used in Nigerian Cities and Their Characteristics

Material Type	Common Use in Nigerian Cities	Origin/Classification	Typical Surface Finish
Laterite blocks	Residential walls (traditional & peri-urban)	Local / earth-based	Exposed or plastered
Adobe	Low-income and rural housing	Local / earth-based	Exposed or lime-plastered
Fired clay bricks	Residential and institutional buildings	Local / processed earth	Exposed brickwork
Sandcrete blocks	Dominant walling material	Conventional	Cement-rendered
Reinforced concrete	Structural frames, slabs	Conventional	Painted or exposed
Metal roofing sheets	Roofing (corrugated/aluminum)	Conventional	Painted or bare metal

Source: Author's compilation (2026)

Proposed Thermal Mitigation Framework for Ibadan

The paper adopts a multi-stage analytical framework to assess the impact of transition from local to industrial materials on the thermal landscape of Ibadan. This process can be divided into four different stages:

Stage 1: Urban Morphology Zoning

The analysis begins with the categorization of Ibadan into three distinct "Thermal Zones" based on historic development and dominant material use:

- Indigenous Core (High Density): "Brown Roofs" (aged iron), laterite/mud walls and narrow street canyons (e.g. Oja'ba, Bere, Yemetu).
- The Transitional Zone (Medium Density): Mixed (older sandcrete bungalows, masonry of colonial times) (e.g. Mokola, Agodi)

- The Modern Periphery (Low Density/Sprawling): Characterized by modern sandcrete blocks, aluminum roofing and a high asphalt coverage (e.g. Akala Express, Moniya).

Stage 2: Material Property Characterization

For each zone, the key building materials are assigned specific thermal variables derived from the reviewed literature:

- Radiative Properties: Albedo (α) and Emissivity (ε) help determining how much solar radiation is reflected vs. absorbed by Ibadan's rooftops.
- Thermal Properties: Conductivity (κ) and Specific Heat (c) help determining the "Thermal Lag" (the time it takes for the afternoon heat to reach the interior of a home in Challenge or Bodija).

Stage 3: Analysis of Heat Interaction and Trade-offs

At this stage, the study looks into the "Albedo Paradox" in the specific geometry of Ibadan. The framework is evaluated based on Tyagi & Danish (2025)

- The Reflection Trap: In crowded areas such as Dugbe, the multiple reflections from high albedo walls may increase the heat load on pedestrians.
- Storage Effect: Asphalt roads in Iwo Road have low albedo, high thermal mass, releasing heat at night (UHI)

Stage 4: Synthesis and mitigation mapping

The last stage relates the performance of the material to the climatic data (solar radiation and humidity) of Ibadan. This leads to a "Mitigation Matrix" suggesting specific interventions:

- Core Strategy: High thermal mass (laterite) and natural ventilation.
- Periphery Strategy: Focus on high-albedo "Cool Roofs" and increased green canopy.

Thermal Behaviour of Building Materials in Ibadan

In Ibadan, the material transition is visible in its skyline. The indigenous core (areas like Bere, Oja'ba, Yemetu and Agbeni) is dominated by aged corrugated iron sheets and thick mud-brick or plaster-coated laterite walls.

- **The "Brown Roof" Effect:** While the iconic "brown roofs" of Ibadan are often viewed through an aesthetic lens, their thermal behavior is critical. Aged, rusted corrugated iron has a significantly lower albedo than new galvanized sheets, absorbing immense solar radiation. However, the high ceilings and steep pitches of the traditional Yorùbá compound house are often a buffer that the modern, low-cost "flat-roof" bungalows in Iwo Road or Challenge do not have.
- **Sandcrete vs. Laterite:** The use of sandcrete blocks in new developments such as Akala Express has increased the thermal conductivity of the city. Unlike the traditional **laterite** found in older Ibadan dwellings, which possesses high thermal mass and "breathes," sandcrete absorbs heat rapidly during the intense afternoon sun (12:00 PM – 3:00 PM) and radiates it indoors well into the night.

Urban AlbedoTrade-offs: The Ibadan Streetscape

Ibadan's organic urban growth creates "canyons" where albedo modification faces significant trade-offs.

- **Reflectivity in Dense Cores:** In the densely packed markets of **Bodie and Dugbe**, introducing high-albedo (cool) pavements could be counterproductive. Because these areas lack significant setback or

vegetation, sunlight reflected off "cool" white-painted walls or light-colored concrete would bounce multiple times within the narrow streets.

- **The Pedestrian Impact:** For the thousands of street vendors and pedestrians in **Mokola**, this reflected radiation increases the **Mean Radiant Temperature (MRT)**. While the building might stay cooler, the person on the street feels a "double hit" of heat: directly from the sun and indirectly from the high-albedo surfaces. This underscores the finding that in Ibadan's high-density zones, **shading (natural or artificial)** is more vital than high albedo alone.

Outdoor Thermal Comfort and the "Informal" Economy

In Ibadan, the "outdoor" is a place of commerce. The thermal properties of the ground cover in areas like **Ojoo or Gate** directly impact the livelihoods of informal traders.

- **Surface Heat Storage:** Conventional asphalt as used in the recent road dualization projects in Ibadan is a huge heat sink. These surfaces can be over 50°C by 4:00 PM, creating a "heat canopy" that lasts long after sunset.

- **Integrated Solutions:** From the discussion, it appears that for Ibadan "Cool Pavements" should emphasize on porosity. Local light-colored stone aggregates could be used for evaporative cooling in permeable paving around bus terminals and markets, taking advantage of Ibadan's high humidity and rainfall to reduce surface temperatures.

Policy and Design Implications for Oyo State

The current **Oyo State Ministry of Lands, Housing and Urban Development** guidelines do not yet account for "Urban Heat Mitigation."

- **Proposed Shift:** There is a need for a "Cool Roof" mandate for new commercial developments in Ibadan.

- **Encouraging the use of local materials:** The policy should encourage the use of compressed earth blocks (CEBs) in public projects (schools, clinics, etc.) to show that they are thermally better than sandcrete.

- **Micro-Climatic Planning**: Urban planning in Ibadan must move beyond "road expansion" to "thermal corridors," ensuring that high-albedo interventions are always paired with the planting of indigenous shade trees like the Azadirachta indica (Neem).

Implications for Outdoor Thermal Comfort and Pedestrian Experience

Outdoor thermal comfort is an important but neglected element of urban sustainability in Nigeria. The literature review shows that thermal comfort is not only dependent on-air temperature but also on mean radiant temperature, humidity and airflow. Cooling air temperatures can be achieved by high-albedo materials but at the same time increase radiant heat load and therefore reduce overall thermal comfort.

In Nigerian cities where pedestrian movement, informal trading and outdoor social interaction are part and parcel of urban life, neglect of pedestrian-scale thermal conditions can compromise urban livability. The discussion implies that strategies to mitigate urban heat should focus on human-scale comfort metrics, rather than simply reducing ambient air temperature. Integrating local building materials with appropriate surface finishes, shading devices, street trees and arcades can significantly enhance outdoor comfort while maintaining acceptable thermal performance.

Relevance to West African Urban Environments

Although the study is focused on Nigeria, the findings have broader relevance for West African cities that

share similar climatic and socio-spatial characteristics. Cities in Ghana, Benin and Côte d'Ivoire experience comparable patterns of rapid urbanization, high solar radiation and limited urban green infrastructure. The dominance of conventional construction materials and the marginalization of local materials are also common regional trends.

The reviewed literature suggests that strategies that emphasize context-sensitive material selection, moderate albedo optimization and integration with vegetation are likely to be effective in the region. However, the discussion also points to the importance of local calibration as differences in urban form, cultural practices and material availability may influence thermal results.

The Mitigation Matrix: Contextual Strategies for Ibadan

The following matrix summarizes the recommended interventions based on the interplay between material thermal properties, albedo, and urban geometry across Ibadan's three primary zones.

Table 4.3: Contextual Relationship Between Urban Zones, Building Materials, Thermal Challenges, and Recommended Strategies in Ibadan

Urban Zone	Dominant Material	Thermal Challenge	Recommended Strategy	Material/Albedo Intervention
Traditional Core (Oja'ba, Bere)	Aged Iron, Laterite, Mud	High nocturnal heat; narrow canyons.	Passive Cooling & Ventilation	Maintain laterite walls; use lime-wash (Moderate Albedo ≈ 0.45) to avoid pedestrian glare.
Transitional (Mokola, Agodi)	Sandcrete, Galvanized Steel	High conductivity; mixed density.	Shading & Surface Modification	Retrofit with Cool Roof coatings; integrate street trees to intercept reflected radiation.
Modern Periphery (Akala, Moniya)	Sandcrete, Aluminum, Asphalt	Rapid daytime heat gain; UHI sprawl.	High Albedo & Green Infrastructure	Mandatory High Albedo Roofs (α>0.60); use permeable light-aggregate pavements.

Source: Author's compilation (2026)

Key Synthesis Points for the Matrix

The "Optimal Albedo" Threshold

The proposed moderate-albedo range of 0.40–0.50 is a conceptual design scenario rather than an experimentally established optimum for Ibadan. Its suitability requires assessment of surface orientation, solar exposure, street-canyon geometry, reflected short-wave radiation, and pedestrian thermal comfort. The range should therefore be treated as a preliminary proposition for field measurement or numerical simulation, not as a validated threshold.

Re-introducing Thermal Mass

The matrix proposes that earth-based materials, including laterite, be considered alongside conventional materials where they meet structural, durability, moisture-protection, and construction requirements. Thermal mass can moderate indoor temperature swings under some conditions, but the benefit depends on wall thickness, conductivity, density, moisture, ventilation, and the timing of heat release. The claim that a material will reduce cooling demand should be verified for the relevant building design.

The "Permeable" Solution for Ibadan's Roads

For major roads, parking areas, and pedestrian spaces in Ibadan, the matrix proposes investigating light-

coloured permeable paving as one possible alternative to dark asphalt. Its thermal and evaporative benefits would depend on aggregate composition, albedo, drainage, retained moisture, shading, and maintenance; local surface-temperature and comfort measurements are needed before quantifying the expected benefit.

- The albedo values shown in the earlier surface-material table are indicative literature values and should be verified for the specific products and surface conditions proposed for Ibadan.
- Potential evaporative cooling should be treated as conditional: it depends on water availability, pore structure, rainfall, drainage, and evaporation rates, and should not be assumed from permeability alone.

CONCLUSION AND RECOMMENDATIONS

The study is brought to a conclusion in this section by synthesizing the findings on the thermal properties of local materials and urban albedo in the specific context of Ibadan, Nigeria. It outlines the major contributions of the research and presents practical, site-specific recommendations for architectural practice, urban planning, and policy. Finally, it identifies the necessary trajectory for future empirical research in the West African sub-region.

Summary of Key Findings

This study reviewed published literature on selected building materials and urban albedo, using Ibadan as a contextual case study. The evidence indicates that thermal conductivity, specific heat capacity, density, and thermal diffusivity vary with material composition, moisture content, and testing conditions. These properties interact with wall thickness, roof construction, ventilation, shading, and urban form to influence indoor and outdoor thermal conditions.

- **The Material Comparison:** Published data do not support a universal ranking of all laterite, adobe, fired clay, and sandcrete products. The comparative table shows variation among sources and highlights gaps in reported parameters. Material selection should therefore be based on verified properties of the actual product and the design conditions.
- **The Albedo Trade-off:** Higher surface reflectance can reduce absorbed solar energy, but its effect on pedestrian comfort depends on the amount and direction of reflected radiation, shading, and urban geometry. This trade-off should be tested in Ibadan rather than assumed from the conceptual review alone.
- **The Proposed Approach:** The study proposes evaluating material selection, surface reflectance, vegetation, shading, and ventilation together. The suggested albedo range of 0.40–0.50 is conceptual and has not been established as an optimum for Ibadan through field measurements or numerical simulation.

Contributions of the Study

This research contributes by synthesising literature on selected building-material properties, interpreting its relevance to Ibadan's contrasting urban forms, and proposing a zonal mitigation framework for future empirical assessment. These contributions are conceptual and should be evaluated through locally grounded testing.

1. **Contextualization:** It contextualizes the global theories of albedo with the morphology of "brown roof" in Ibadan and gives a localized understanding of the Urban Heat Island (UHI).
2. **Conceptual Innovation:** It places local materials as active cooling agents, and not "low-cost" alternatives, thus providing a scientific basis for their re-entry into modern design.

3. **Framework Development:** The study proposes a Zonal Mitigation Matrix (Traditional Core vs. Modern Periphery) as a framework for climate responsive urban management in West Africa.

Recommendations

Recommendations for Architectural Practice

- **Zone-Specific Selection:** Architects in Ibadan are advised to use Stabilized Earth Blocks (SEBs) in low-rise residential projects to take advantage of thermal mass.
- **Reflectivity Management:** Suburban Ibadan roofs (e.g., Akala Express) should be coated with high-albedo "cool roof" coatings, and wall finishes in dense areas should be limited to moderate-reflectivity lime washes to safeguard pedestrian comfort.
- **Integrated Passive Design:** Material selection should be integrated with deep overhangs and ventilated attics to minimize inherent heat of metal roofing sheets.

Recommendations for Urban Planning and Design

- **Thermal Zoning:** Planning authorities (e.g. Oyo State Ministry of Lands and Housing) should establish "Thermal Mitigation Zones". Emphasis should be on shading and ventilation in high-density cores and on albedo and green cover in low-density peripheries.
- **Permeable Infrastructure:** Convert public parking lots and pedestrian walkways in Ibadan from dark asphalt to light-colored permeable pavers to promote evaporative cooling.

Policy and Regulatory Recommendations

- **Building Code Reform:** Relevant authorities could examine whether climate-zone-specific thermal transmittance and solar-reflectance guidance would be appropriate for Nigerian building regulations, subject to technical evidence, feasibility assessment, and consultation with practitioners.
- **Incentives for local materials:** The government should consider tax rebates or faster planning approvals for developers who use local thermally efficient materials such as laterite and clay.

Areas for Further Research

1. **Empirical Validation:** Measure thermal properties of locally sourced materials and monitor indoor/outdoor temperature, humidity, surface temperature, and pedestrian comfort in representative Ibadan neighbourhoods. Use numerical tools such as ENVI-met or building-energy simulation only after selecting suitable local input data and validating model assumptions.
2. **Aging Studies:** Long-term albedos of "cool" materials under the high dust (Harmattan) and humidity conditions of Ibadan.
3. **Socio-Cultural Perception:** Study of willingness of people of Ibadan to accept "earth-based" materials for modern high-status housing projects.

Concluding Remarks

This study relies on secondary literature and does not include original laboratory measurements, field monitoring, or numerical simulations for Ibadan. The studies reviewed use different material formulations, sample preparation procedures, moisture conditions, test methods, and reporting conventions, which limits direct comparison. Some sources do not report all four thermal parameters, and calculated values are only as reliable as the input data. The proposed mitigation matrix and albedo scenarios are conceptual recommendations, not validated predictions of temperature reduction or pedestrian comfort in specific Ibadan

neighbourhoods. Future research should test locally sourced materials under controlled moisture conditions, measure representative walls and roofs, and validate any numerical models against field observations.

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