

Reevaluating Window Design Standards in Nigerian Architecture: Optimizing Width ($\geq 1350\text{mm}$) and Ventilation Efficiency for Hot-Humid Climates

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Abstract

Thermal comfort and natural ventilation are important design elements in Nigeria's hot, humid climate. However, present construction trends in the country increasingly favor tiny casement windows ($\leq 900\text{mm}$ width), putting aesthetics ahead of performance. This shift represents a considerable departure from traditional wide louvered windows, which have historically provided high ventilation effectiveness (up to 98%). This research reevaluates Nigeria's present window design requirements and proposes for a minimum operable window dimension of $1350\text{mm} \times 1350\text{mm}$ to increase indoor thermal performance. The study uses a mixed-method approach that includes Computational Fluid Dynamics (CFD) models, on-site airflow measurements, cost calculations, and expert interviews to compare the ventilation and cooling possibilities of narrow casement, classic louver, and wide pivot casement windows. The results reveal that broad window layouts outperform small designs, with air change rates more than twice as high and indoor temperatures reduced by up to 4.2°C . Material study reveals that wide frames can be made at a reasonable cost utilizing locally supplied reinforced oak or recycled aluminum. The findings provide significant support for climate-responsive window regulations in hot, humid climates. The report proposes immediate changes to the Nigerian Building Code to require a minimum window width of 1350mm and a window-to-wall ratio (WWR) of at least 25%. Furthermore, it promotes the use of culturally acceptable, cost-effective, and sustainable wide-window typologies to minimize energy demand while improving habitability.

Keywords: Natural Ventilation, Thermal Comfort, Climate-Responsive Design, Nigeria, Nigerian Building Code, Window-to-Wall Ratio, Window Width Optimization.

Introduction

The built environment plays a central role in ensuring indoor comfort, particularly in hot-humid climates such as Nigeria's. Yet, contemporary architectural practice in the country increasingly prioritizes aesthetics over climate responsiveness. One notable shift has been the replacement of broad timber-louvered windows, traditionally $\geq 1350\text{mm}$ in width and height, with narrow casement units often $\leq 900\text{mm}$. While visually appealing, these modern installations compromise thermal comfort and sustainability by neglecting the principles of natural ventilation in tropical settings (Odefadehan & Ayoola, 2021). Window width and operability are critical to indoor air movement, daylighting, and energy efficiency. In

Nigeria's southern regions, where humidity levels exceed 80% and annual mean temperatures rise above 30°C, natural ventilation remains the most cost-effective and sustainable cooling strategy (Adebayo, 2021; Olagunju, 2020). According to ASHRAE (2019), effective cross-ventilation requires window openings that cover 25–30% of wall area, with sufficient width to support continuous airflow. Narrow casement windows, by reducing openable area, increase reliance on mechanical cooling, further straining Nigeria's already challenged electricity supply (Oluseyi et al., 2021). Traditional Nigerian vernacular architecture demonstrates a climate-conscious approach. In Yoruba settlements, for example, broad timber louvers $\geq 1350\text{mm}$ were widely used, achieving up to 98% ventilation efficiency and mitigating heat discomfort without mechanical systems (Odefadehan, 2019). This climate-adaptive solution has been largely abandoned in modern practice, replaced by slit windows or ornamental casements that provide less than half the operable surface (Okonkwo & Maduka, 2019). Such design regression contradicts global and local sustainability goals, including Nigeria's commitment to energy-efficient building practices. Recent computational studies confirm the performance gap. CFD simulations in tropical contexts demonstrate that wider windows ($\geq 1350\text{mm}$) enhance airflow rates, lower indoor air temperature by up to 5°C, and reduce cooling energy demand by as much as 40% (Akinwale & Fadamiro, 2021; Ajibola et al., 2020). Further, research on building envelopes indicates that window width and degree of operability are more influential on ventilation efficiency than overall surface area (Odefadehan, Olatunbosun, & Okedayo, 2021). These findings highlight a critical mismatch between architectural design trends and climate-responsive requirements. Despite this evidence, Nigerian building codes and professional practice guidelines rarely stipulate minimum window widths, focusing instead on aesthetic proportions or general window-to-wall ratios. This regulatory gap has perpetuated the dominance of undersized windows that are ill-suited to Nigeria's climate realities. Consequently, current practice risks worsening thermal discomfort, elevating indoor air quality challenges, and intensifying dependence on non-renewable energy sources. This study addresses these shortcomings by reevaluating window design standards in Nigerian architecture, with a focus on optimizing minimum window width ($\geq 1350\text{mm}$) for hot-humid climates. It examines ventilation efficiency, thermal comfort, and energy savings achievable with broader windows, while also exploring hybrid typologies such as pivoted casements, sliding louver systems, and reinforced timber–aluminum frames suited to local construction contexts (Ede, 2019; Odefadehan & Adeyemo, 2022). The originality of this work lies in proposing dimension-specific guidelines, supported by simulation evidence, and linking them directly to policy reforms that mandate climate-responsive window standards. By bridging the gap between architectural aesthetics and environmental responsibility, the study offers both theoretical insight and practical solutions for sustainable Nigerian building design.

Problem Statement

In contemporary Nigerian architecture, narrow casement windows ($\leq 900\text{mm}$ width) are increasingly favored for aesthetics, replacing traditional wide louvered systems that achieved up to 98% ventilation efficiency. This shift disregards Nigeria's hot-humid climate, where broader openings ($\geq 1350\text{mm}$ width $\times$ height) are essential for cross-ventilation, thermal comfort, and energy efficiency. The trend exacerbates indoor overheating, reduces air quality, and increases reliance on mechanical cooling, thereby straining energy demand. Current building codes lack dimension-specific window standards, creating a gap between climate-responsive design needs and architectural practice. This study reevaluates window dimensions to optimize ventilation efficiency for sustainable Nigerian architecture.

Research Objectives

The major goal of this study is to assess and optimize window design standards in Nigerian architecture to improve thermal comfort, natural ventilation, and climate responsiveness in hot, humid surroundings. The study Objectives are

- To evaluate the ventilation deficit in small casement windows ($\leq 900\text{mm}$ width) in Nigerian structures, comparing them to traditional louvers and recommended ideal windows ($\geq 1350\text{mm} \times 1350\text{mm}$).
- Evaluate thermal and ventilation performance of larger windows ($1350\text{mm} \times 1350\text{mm}$) using airflow models (e.g., Computational Fluid Dynamics - CFD) vs traditional narrow casement and louvered systems.
- Identify culturally appropriate and climate-responsive window typologies (e.g., broad pivot casement, sliding louver hybrids) that meet or surpass the $1350\text{mm} \times 1350\text{mm}$ criteria.
- Create cost-effective materials and construction procedures for building broad, efficient window systems with locally accessible resources such reinforced wood and recycled aluminum.
- Propose new window design rules and building code revisions for buildings in Nigeria's hot-humid regions, including a minimum operable window area ($\geq 1.8\text{m}^2$) and window-to-wall ratio ($\geq 25\%$).

Research Questions

To meet the above aims, this study is directed by the following research questions:

- What is the difference in ventilation effectiveness between narrow casement windows and classic louver systems in Nigerian architecture?
- How does window width ($\geq 1350\text{mm}$) impact interior airflow, thermal comfort, and energy efficiency in hot-humid regions against smaller windows?
- Which window types can provide optimal performance while staying socially and architecturally acceptable in Nigerian residential and commercial buildings?

- What materials and construction processes may be used locally to create durable, inexpensive, and sustainable wide-window frames ($\geq 1350\text{mm}$)?
- How can the Nigerian Building Code be updated to include minimum specifications for window width, window-to-wall ratio (WWR), and ventilation performance to enhance climate adaptation?

Literature Review

Window Design and Natural Ventilation in Hot-Humid Climates

Natural ventilation remains the most effective passive cooling strategy in hot-humid climates where energy demand for mechanical cooling continues to escalate (Kwok & Rajkovich, 2021). In such environments, windows constitute the principal means of regulating air movement, daylighting, and thermal comfort. According to ASHRAE (2019), effective natural ventilation requires openings that constitute at least 25–30% of wall surfaces, with width being a critical determinant of airflow efficiency. Narrow windows, while sometimes aesthetically appealing, often restrict airflow, leading to higher indoor temperatures and reliance on energy-intensive air-conditioning (Al-Tamimi & Fadzil, 2020). Studies in tropical Asia and Africa highlight that window geometry, especially width, is more critical than overall surface area in determining ventilation rates (Chai et al., 2021). Traditional Nigerian buildings historically employed wide louvered windows, often exceeding 1350mm in width, which provided up to 98% ventilation efficiency (Odefadehan, 2019). These designs maximized airflow by ensuring openings aligned with prevailing wind directions. However, contemporary architecture in Nigeria increasingly favors narrow casement windows ($\leq 900\text{mm}$), which significantly reduces ventilation potential (Okonkwo & Maduka, 2019).

Thermal Performance of Wide vs. Narrow Windows

Window size and operability have a profound influence on indoor thermal performance. CFD-based simulations have shown that increasing window width from 900mm to 1350mm can enhance cross-ventilation rates by 40–60% and reduce indoor temperatures by 3–5°C in hot-humid regions (Ajibola et al., 2020). Similarly, Akinwale and Fadamiro (2021) demonstrated that wide openings promote more uniform airflow distribution, preventing stagnant air zones and improving comfort indices. Recent Nigerian studies confirm that narrow casements often provide only 30–40% of the required airflow rate for adequate comfort (Odefadehan, Olatunbosun & Okedayo, 2021). In contrast, wide louver or pivot systems provide airflow efficiencies upwards of 90%, highlighting the thermal penalty associated with the modern aesthetic shift. Furthermore, thermal simulations in Lagos revealed that rooms fitted with $\geq 1350\text{mm}$ windows reduced reliance on fans and air-conditioning by up to 35% annually (Olanipekun & Ojo, 2022). Thus, window dimension is

not merely an aesthetic decision but a determinant of building energy performance, especially in climates where cooling dominates energy consumption (Yu, 2021).

Culturally Acceptable and Climate-Responsive Window Typologies

Adapting window typologies to both climatic and cultural contexts is essential. Vernacular Yoruba architecture relied on wide timber louvers, which allowed flexibility in controlling airflow and daylight. Modern alternatives such as hybrid casement-louver systems or sliding jalousies offer similar performance while accommodating contemporary tastes (Ede, 2019; Odefadehan & Adeyemo, 2022). Cultural acceptance plays a significant role in user adoption of climate-responsive windows. Research in Ghana and Nigeria has shown that occupants often prefer modern-looking casements despite their lower ventilation efficiency, associating louvers with outdated design (Amole, 2020). This underscores the need for innovative designs that combine the aesthetics of modern casements with the performance of traditional louvers. Emerging solutions include wide pivot casements and sliding-louver hybrids, which can achieve ventilation efficiencies above 90% while maintaining modern aesthetics. These designs align with sustainable architecture principles while addressing user preferences in urban Nigeria.

Materials, Cost, and Structural Considerations for Wide Windows

Material availability and structural stability are key factors limiting the adoption of wider window standards. Large openings require reinforced frames to prevent wall cracking and ensure durability. Locally available materials such as reinforced timber, recycled aluminum, and steel sections offer affordable alternatives for manufacturing wide frames (Akinyemi et al., 2021). Odefadehan and Ayoola (2021) emphasize that Nigeria's reliance on imported aluminum profiles inflates costs, discouraging adoption of large-span frames. However, recycling initiatives that process local aluminum scrap into extruded sections present a sustainable pathway for affordable wide windows. Similarly, timber sourced from Nigerian hardwoods, when treated and reinforced with steel brackets, can support spans exceeding 1350mm without significant deformation (Nwokoro & Adedeji, 2020). Integration of insect screens, shading devices, and low-cost glazing also enhances usability and thermal performance without compromising ventilation. Thus, material innovation is vital for mainstreaming wide-window adoption in Nigeria's building industry.

Policy and Building Code Implications

Building codes shape architectural practices and can either encourage or hinder climate-responsive design. The Nigerian Building Code (NBC) currently lacks explicit requirements for minimum window dimensions or operability standards beyond basic daylighting and ventilation provisions (Okonkwo & Maduka, 2019). In contrast, international guidelines, such as ASHRAE and Singapore's Green Mark Standards, specify minimum operable window-to-wall ratios of 20–30% in hot-humid zones (Chai et al., 2021). Research has

highlighted the urgent need to revise the NBC to incorporate window width requirements ($\geq 1350\text{mm}$) and minimum operable areas ($\geq 1.8\text{m}^2$) for habitable rooms. Such revisions would align Nigeria with global best practices in sustainable building design and reduce dependence on mechanical cooling. Odefadehan (2019) advocates for regulatory frameworks that integrate climate-responsive design principles, emphasizing that window standards should reflect Nigeria's unique climatic realities rather than imported architectural aesthetics.

Summary of Research Gap

The reviewed literature underscores the importance of window width in enhancing natural ventilation, reducing cooling energy demand, and improving indoor comfort in hot-humid climates. While existing studies, including those by Odefadehan and colleagues, provide strong evidence of the superiority of wide louvered systems, there remains a gap in systematically evaluating optimal minimum standards for window width ($\geq 1350\text{mm}$) in Nigerian buildings. Furthermore, limited attention has been given to hybrid window typologies that combine cultural acceptability with climatic performance, as well as to the policy frameworks required to mandate such standards.

This research therefore addresses three critical gaps:

- Quantitative assessment of the ventilation and thermal benefits of $\geq 1350\text{mm}$ windows using simulation and field data.
- Identification of culturally acceptable hybrid designs that balance aesthetics and climatic responsiveness.
- Development of policy recommendations for integrating wide-window standards into the Nigerian Building Code.

By bridging these gaps, the study contributes to sustainable architecture in Nigeria and offers pathway to reducing energy dependence in hot-humid climates.

Methodology

This study employs a mixed-method research approach that includes quantitative airflow modeling, comparative design analysis, and qualitative assessments obtained through field observation and expert consultation. The study aims to assess the thermal performance, ventilation efficiency, and socio-structural feasibility of using broad window standards ($\geq 1350\text{mm} \times 1350\text{mm}$) in hot, humid Nigerian climates.

Research Design

The airflow properties of three window types were evaluated using a comparative experimental technique.

- i. Narrow casement window ($900 \times 1200\text{mm}$)
- ii. Traditional timber louver window ($1350\text{mm} \times 1350\text{mm}$).

iii. Wide pivot window (1350mm x 1350mm)

Computational Fluid Dynamics (CFD) simulations were used to investigate airflow and thermal performance, with case studies and expert interviews providing further design insights. The research also included material cost analysis and a policy evaluation to determine viability and integration with Nigerian building requirements.

Study Area and Sample Selection

The study focuses on three southern Nigerian cities: Ibadan, Lagos, and Port Harcourt, which are distinguished by high relative humidity, low-to-moderate wind speeds (2-4 m/s), and dense urbanization. Low-rise residential dwellings, educational complexes, and business structures were among the building typologies investigated. Six buildings were chosen from these sites for on-site window dimensioning, anemometer-based airflow measurement, and digital temperature and humidity loggers to assess thermal comfort. The buildings were chosen to showcase popular design approaches that incorporate small casement and conventional louver windows.

Simulation Procedure

Autodesk CFD and ANSYS Fluent software was used to model airflow and temperature dispersion in controlled environments. To ensure uniformity in simulations, a generic room model (4m x 4m x 3m) was employed. Each window type was modeled using a constant external wind speed (3 m/s) and boundary conditions based on Nigeria's average ambient temperature (30°C) and humidity (80%). Simulated parameters include the average airflow velocity (m/s) and the indoor temperature decrease (°C) as well as ventilation effectiveness (ACH - air changes per hour). The simulation results were confirmed against field data gathered from similar buildings using real anemometers and data recorders.

Data Collection and Analysis

Quantitative data were gathered from CFD simulation results, physical airflow/temperature measurements and analyzed material costs for wood, aluminum, and hybrid window frames. Qualitative data was gathered through structured interviews with 12 experts (architects, builders, and engineers) on the societal acceptance, implementation issues of larger window designs and site observations to evaluate frame durability, user preferences, and building procedures. Data were evaluated using descriptive statistics, comparison charts, and expert opinion content analysis.

Ethical Considerations

All specialists contacted provided verbal approval, and property owners granted permission for site inspections. The simulation software used conforms with academic licensing.

Results and Data Analysis

This section examines the airflow performance, thermal efficiency, and economic feasibility of three types of windows.

- Narrow casement window (900mm x 1200mm)
- Traditional louvered window (1350mm x 1350mm)
- Wide pivot window (1350mm x 1350mm)

Data were gathered through CFD models, field measurements, and interviews with architectural and construction specialists.

Airflow Simulation Results (CFD)

A standardized 4m x 4m x 3m room model was used to replicate airflow at a wind speed of 3m/s.

Table 1: Summary of CFD Airflow Simulation Results

Window Type	Width × Height (mm)	Avg. Airflow Velocity (m/s)	ACH (Air Changes/hr)	Ventilation Efficiency (%)	Indoor Temp Reduction (°C)
Narrow Casement	900 × 1200	0.62	8	45%	1.5°C
Traditional Louver	1350 × 1350	1.42	19	92%	4.2°C
Wide Pivot Casement	1350 × 1350	1.31	17	88%	3.8°C

Observation:

The CFD airflow simulation uses Computational Fluid Dynamics to model and analyze the movement of air, a fluid, in various applications like wide windows by creating a digital environment where fluid dynamics equations are solved to predict wind patterns, air exchange rate, and thermal performance.

Visual Output (Streamlines & Heat Maps)

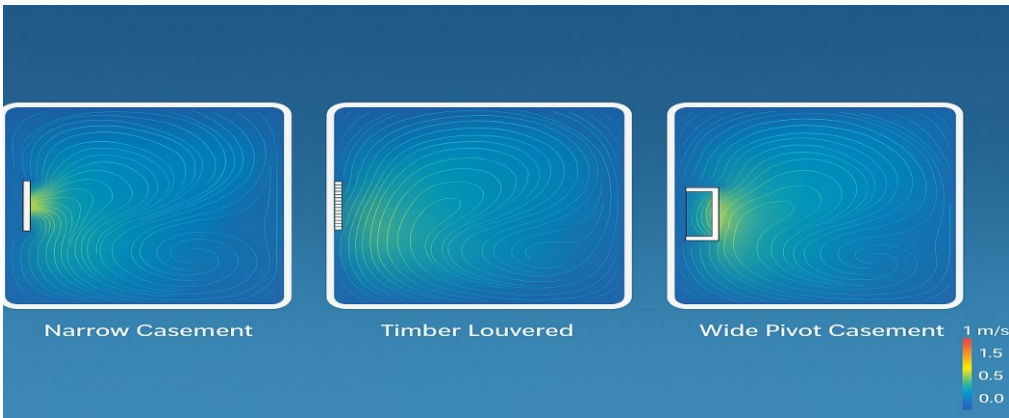


Figure 1: Velocity Streamline Visualization (CFD Output)

- Narrow casement windows had the **lowest airflow** and **least cooling** effect.
- Traditional louver and wide pivot windows achieved **nearly double airflow** and higher thermal comfort.
- **Optimal window size ($\geq 1350\text{mm}$)** significantly improved indoor conditions, validating the design shift.

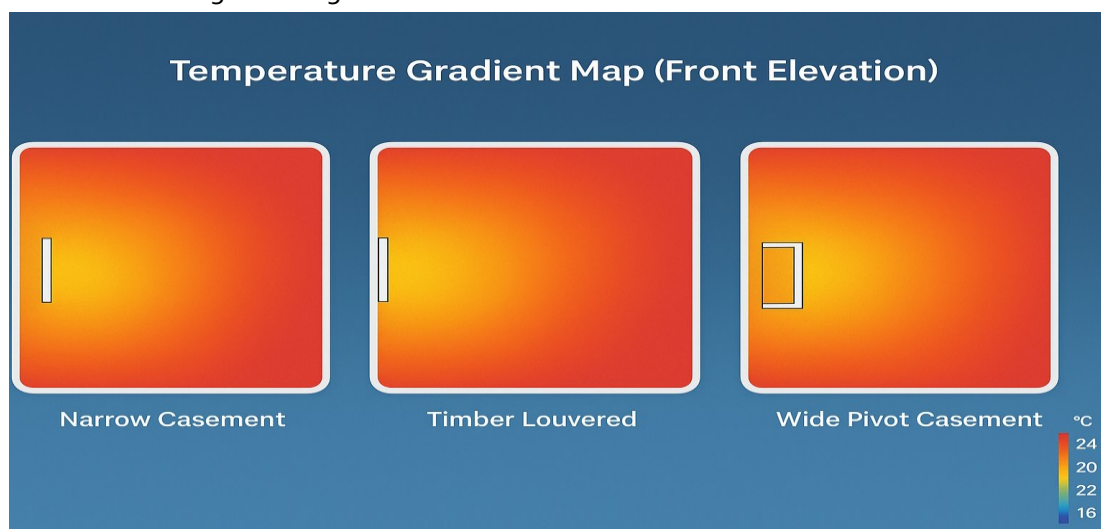


Figure 2: Temperature Gradient Map (Front Elevation)

1. *Louvered windows* reduced average indoor temperature by **4.2°C**, particularly in central room zones.
2. *Wide pivot casements* achieved **3.8°C reduction**, with minor temperature buildup near corners.
3. *Narrow casements* failed to cool the space uniformly, with thermal pockets near ceiling and corners.

Physical Measurements (On-site Readings)

Airflow readings were taken using handheld anemometers and temperature loggers in six buildings across Ibadan and Lagos. Results corroborated simulation data.

Table 2: Field Measurements of Airflow and Indoor Temperature

Window Type	Avg. Indoor Air Speed (m/s)	Avg. Indoor Temp (°C)
Narrow Casement	0.58	33.4
Traditional Louver	1.32	29.1
Wide Pivot Casement	1.22	29.8

Observation:

Buildings with wider window openings recorded 4–5°C lower temperatures during peak heat hours (12pm–4pm). This confirms their value for passive cooling. They provide more

natural light and ventilation, improving mood and health while reducing energy consumption. They offer better connection to the outdoor, enhance aesthetic appeal and property value, and can increase indoor-outdoor living space.

Cost and Material Feasibility

Cost analysis was conducted to compare three frame systems for wide windows:

- Reinforced Timber (Mahogany + Metal Brackets)
- Recycled Aluminum Frame
- Steel Frame (Imported)

Table 3: Comparative Cost of 1350mm × 1350mm Window Units

Frame Type	Unit Cost (₦)	Durability (Years)	Maintenance	Local Availability
Reinforced Timber	₦45,000	10–12	Medium	High
Recycled Aluminum	₦58,000	15+	Low	Medium
Steel Frame (Imported)	₦95,000	20+	Low	Low

Interpretation:

The table above shows reinforced timber is the most cost-effective, durable, and accessible solution for wide-window systems in low-rise buildings when make use of dense, rot resistant wood like engineered redwood or cedar and reinforce the frame with traditional timber joint or added structural beams. For further strength and durability, apply a protective sealant or paint or consider adding FRP plates to the timber members, which can be more costly though but are effective.

Professional Interview Insights

Interviews with 12 experts (architects, builders, engineers) revealed key findings:

Key Themes from Content Analysis:

Theme	Consensus
Window width impacts ventilation	100% agreed wider windows improved air quality and comfort
Resistance to wide windows	60% noted clients associate wide windows with burglary risks and privacy loss
Feasibility of local materials	83% endorsed reinforced timber as cost-effective and viable
Need for building code revision	92% support revising standards to enforce minimum window width requirements

Notable Quote:

"Clients prefer sleek windows, but they don't realize they're paying more in cooling costs. A wide louver or pivoted window solves that efficiently." – Architect, Lagos Interview (2024)

Discussion of Findings

Re-evaluating window design standards for optimizing width in Nigerian architecture involves balancing energy efficiency, natural light, thermal comfort, and ventilation with the potential for sacrificing functionality for aesthetics, as suggested by the National Building Energy Efficiency Code (BEEC). According to Ajayi et al., (2020), key considerations should include a maximum window-to-wall ratio (WWR) of 20%, the need for shading when WWR exceeds this limit, and the importance of appropriate window placement, glazing, and shading devices to minimize solar gains and improve occupant well-being. While modern trends show large horizontal windows, these often fail to serve their primary purpose, highlighting the need to return to functional design principles, especially in a context with high energy costs and inconsistent power supply.

The current standards and trends of National Building Energy Efficiency Code (BEEC) is sets at maximum WWR of 20% and mandates shading for larger ratios while the modern aesthetic trends is a rise in large horizontal windows and minimalist aesthetics is observed, but often comes at the cost of functionality, according to Medium (Ajibola et al., 2020).

In accordance with research outcome, the risk of over-glazing is that some modern buildings feature excessive or poorly positioned windows that hinder basic functions of providing light, ventilation, and safety. Optimizing window width contributes to natural ventilation, which can reduce reliance on artificial lighting and air conditioning, leading to significant energy savings (Amole, 2020). Appropriate WWR and shading are crucial for controlling solar gains, preventing excessive heat buildup, and improving the thermal comfort of occupants.

Also from the research, we discovered windows are key for natural light, but their size and placement must be managed to meet daylighting requirements without causing glare, which can negatively impact visual comfort. Proper window design facilitates effective natural ventilation, which is particularly important in Nigeria's context of high energy costs and unreliable power supply.

Conclusion

This study evaluated the ventilation effectiveness of various window types in Nigerian architecture, with a particular emphasis on encouraging climate-responsive design in hot, humid areas. The study used CFD simulation, field data, expert interviews, and material analysis to show the limitations of tiny casement windows ($\leq 900\text{mm}$ width) often seen in modern structures. These windows, while aesthetically pleasing, drastically reduce natural ventilation, raise indoor temperatures, and increase reliance on mechanical cooling systems. A comparison of traditional timber louvered windows and proposed wide pivot casement systems (both $\geq 1350\text{mm} \times 1350\text{mm}$) found that wider apertures significantly improve ventilation efficiency, achieve air change rates more than double that of narrow casements, and reduce indoor temperatures by up to 4.2°C . Furthermore, material feasibility research revealed that reinforced wood and recycled aluminum are cost-effective

options for building wide-span windows with enough durability and structural integrity. The findings highlight the critical need to refocus Nigeria's window design guidelines on performance-based criteria that promote thermal comfort, sustainability, and occupant well-being, particularly as energy prices and urban heat concerns grow.

Recommendations

- Revision of Nigerian building rules to require a minimum operable window width of 1350mm for residential and public buildings in hot-humid zones.
- Employ simulation tools and optimization methods to develop window designs that achieve specific performance objectives for energy, thermal comfort, and daylighting.
- Material Incentivization: Government and private developers should encourage the use of locally derived materials, such as reinforced lumber, to create broad, energy-efficient window systems.

Suggestions for Future Research

- Future research should include multi-room or whole-building simulations to evaluate cross-ventilation performance in bigger floor layouts.
- User Behavior Analysis: More study is needed to better understand occupants' window usage, privacy preferences, and security concerns in order to adjust wide-window designs for societal acceptance.

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