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BEYOND THE BLOCK: BUILDING MATERIAL CHOICE, INDOOR ENVIRONMENTAL QUALITY AND PUPIL WELL-BEING IN NIGERIAN PRIMARY SCHOOLS

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Abstract

In the hot-humid climate of South East Nigeria, classroom overheating poses a persistent indoor environmental quality (IEQ) challenge with direct consequences for pupil comfort and learning conditions. This paper presents a comparative field investigation of Sandcrete Block (SCB) and Interlocking Compressed Earth Block (ICEB) classrooms across six paired primary schools in Anambra State, combining in-situ thermal monitoring with structured pupil thermal response surveys (n = 257) conducted under normal operational conditions. ICEB classrooms recorded a statistically significant mean indoor air temperature reduction of approximately 2.03°C (t = 6.83, p < 0.01) relative to SCB counterparts, alongside reduced diurnal thermal variability during occupied hours. Occupant perception data corroborated physical measurements, with pupils in ICEB classrooms reporting systematically improved thermal sensation, preference, and acceptability. The findings establish building material selection as a primary determinant of indoor environmental quality in resource-constrained tropical schools, with direct implications for educational infrastructure policy and pupil well-being.

Keywords: Indoor environmental quality; thermal comfort; Interlocking Compressed Earth Blocks; Sandcrete Blocks; tropical schools; environmental health.

1. INTRODUCTION

In naturally ventilated primary schools across South East Nigeria, the building envelope functions as the sole environmental moderator in the absence of mechanical cooling. The dominant construction system, Sandcrete Block (SCB), has largely displaced traditional earthen materials despite exhibiting higher thermal conductivity and lower thermal inertia — characteristics that amplify indoor temperature swings and prolong periods of elevated heat stress during peak solar exposure.

Children are physiologically more vulnerable to thermal extremes than adults, with higher metabolic rates and reduced thermoregulatory efficiency rendering them susceptible to heat-related cognitive impairment (Teli, Jentsch and James, 2012). Sustained classroom overheating is directly associated with diminished concentration and measurable reductions in task efficiency (Wargocki and Wyon, 2007; Park et al., 2020). Yet building material selection in Nigerian school construction continues to be treated primarily as a structural and economic decision rather than an environmental health variable.

Interlocking Compressed Earth Blocks (ICEB) represent a stabilised evolution of earthen construction, combining locally sourced soil with improved structural regularity. Laboratory evidence indicates significantly lower thermal conductivity for ICEB relative to SCB systems (Danjuma, 2020; Fakinlede and Akinleye, 2018), suggesting passive thermal benefit at the material level. However, field-based evidence directly linking ICEB construction to occupant thermal comfort under operational school conditions remains limited. This study addresses that gap through paired monitoring and occupant survey data across six schools in Anambra State.

2. LITERATURE REVIEW

Adaptive thermal comfort theory provides the most appropriate conceptual basis for evaluating classrooms in hot-humid climates, particularly where occupants have limited environmental control over their thermal environment (Humphreys, Nicol and Roaf, 2007; ASHRAE, 2020). Within this framework, comfort is understood as a dynamic response to prevailing conditions rather than a fixed thermal setpoint, making it especially relevant to naturally ventilated school buildings where mechanical intervention is absent.

Traditional earth-based construction systems have long been recognised for superior hygrothermal performance in tropical climates, offering passive regulation of indoor temperature and humidity through high thermal mass (Adegun and Adedeji, 2017). Despite these advantages, adoption of earthen systems has declined sharply in favour of Sandcrete Block construction, which now dominates contemporary Nigerian building practice (Akinyoade, 2016). Interlocking Compressed Earth Blocks (ICEB) represent a stabilised evolution of earthen construction, combining locally sourced soil with improved structural regularity and durability.

Despite established material-level advantages demonstrated at laboratory scale (Danjuma, 2020; Fakinlede and Akinleye, 2018), a persistent gap exists in field-based evidence linking ICEB construction to lived comfort outcomes in real, operational school environments. This study addresses that gap by evaluating paired SCB and ICEB classrooms under identical climatic and occupancy conditions across six schools in Anambra State.

3. STUDY AREA AND METHODS

3.1 Case Study Schools

The study is situated in Anambra State, South East Nigeria, within a hot-humid tropical climate characterised by the seasonal influence of the Intertropical Convergence Zone (ITCZ). Six public primary schools were selected across three administrative zones — Anambra North, Anambra Central, and Anambra South — each containing paired SCB and ICEB classrooms, enabling direct comparative analysis under comparable climatic exposure. Total monitored occupancy was 257 pupils across the twelve classrooms (Table 1).

Table 1. Case Study Schools and Classroom Occupancy (n = 257), Anambra State, July 2024

School Site	SCB Occupancy (n)	ICEB Occupancy (n)	Monitoring Date
Aguluezechukwu	26	19	12 July 2024
Akwaeze	21	20	4 July 2024
Awkuzu	20	21	2 July 2024
Nkwelle	24	20	3 July 2024

Ufuma	22	20	16 July 2024
Umuoji	23	21	19 July 2024

3.2 Field Monitoring and Survey Protocol

Indoor air temperature (T_a) was recorded continuously at 15-minute intervals using calibrated data loggers at occupant breathing height (1.2 m above floor level) during school operational hours (08:00–14:00). Outdoor reference conditions were obtained from ERA5 reanalysis datasets to ensure consistent boundary conditions across all sites. A Standardised Morning Ventilation Protocol (SMVP) was applied, maintaining windows open during core teaching hours and closed thereafter, controlling for airflow variability as a confounding variable.

Pupil thermal perception was assessed via structured questionnaires capturing three indices: Thermal Sensation Vote (TSV, 7-point scale), Thermal Preference Vote (TPV), and Thermal Acceptability Vote (TAV). A total of $n = 257$ pupils participated across the twelve classrooms. Monitoring was conducted in July 2024 — the peak wet season — to ensure meteorological comparability across sites. Comparative analysis used paired t-tests to evaluate mean temperature differentials, with Cohen's d for effect size.

(a) SCB classroom — casement window system

(b) ICEB classroom — permanent screen wall ventilation

Figure 1. Comparative Envelope Configurations — SCB and ICEB Classroom Types

4. RESULTS

4.1 Indoor Air Temperature

Across all six paired sites, ICEB classrooms consistently recorded lower mean indoor air temperatures than SCB counterparts under equivalent climatic and occupancy conditions. The aggregated mean temperature reduction was 2.03°C ($t = 6.83$, $p < 0.01$), sustained throughout core occupancy hours. At Awkuzu, the SCB classroom reached a peak temperature of 32.6°C, while the ICEB classroom maintained a substantially moderated indoor profile. ICEB buildings also exhibited reduced diurnal thermal fluctuation, confirming stronger thermal damping behaviour attributable to their higher thermal mass and lower conductivity relative to SCB systems.

4.2 Occupant Thermal Perception

Pupil responses aligned closely with measured environmental conditions, with aggregated results from the n = 257 sample demonstrating a consistent comfort advantage for ICEB classrooms across all three perception indices (Table 2).

Table 2. Comparative Occupant Thermal Perception Indices, by Range Across Sites (n = 257)

Perception Index	SCB Classrooms	ICEB Classrooms
TSV (within comfort range: −1, 0, +1)	58% to 73%	84% to 90%
TPV (Neutral / “Okay” preference)	Consistently low; pupils predominantly voted “Cooler”	Up to 68% (Aguluezechukwu)
TAV (“Comfortable” rating)	As low as 29% (Akwaeze)	As high as 86% (Awkuzu)

The TSV data show a substantial divergence in the proportion of pupils reporting comfortable sensations: between 84% and 90% of ICEB-classroom respondents fell within the comfort band, compared with only 58% to 73% in SCB classrooms. TPV responses showed a similar pattern, with neutral (“Okay”) preference reaching 68% in the ICEB classroom at Aguluezechukwu, while SCB respondents across sites consistently favoured cooler conditions. The TAV data revealed the widest site-level divergence: the ICEB classroom at Awkuzu recorded 86% acceptability, while the SCB classroom at Akwaeze recorded as low as 29%.

The alignment between objective measurement and subjective perception strengthens confidence in the observed performance differential, indicating that the 2.03°C mean temperature reduction translates into substantial and consistent improvements in lived classroom conditions for pupils.

5. DISCUSSION

The thermal advantage recorded in ICEB classrooms is primarily attributable to differences in envelope thermophysical properties. ICEB systems exhibit greater thermal inertia and lower conductivity than SCB, delaying heat transmission and attenuating external thermal loads during peak solar exposure (Mba, Sam-Amobi and Okeke, 2022). This produces lower midday temperature peaks and a more stable indoor environment across occupied hours — conditions directly beneficial to learning, where thermal consistency supports cognitive focus and reduces physiological heat stress (Wargocki and Wyon, 2007).

The results also confirm that material performance does not operate in isolation. Ventilation behaviour, occupancy density, and external climatic conditions all mediated the magnitude of thermal benefit observed across sites. This positions the building envelope as one element within a coupled envelope–ventilation–occupancy system and confirms that material substitution must be accompanied by appropriate ventilation design and occupancy management to realise full IEQ benefit.

The alignment between TSV, TPV, and TAV responses and measured temperatures supports the applicability of adaptive comfort principles in this context (Humphreys, Nicol and Roaf, 2007; ASHRAE, 2020). Even a modest 1°C reduction produces measurable perceptual improvements among child occupants — a population known to be more sensitive to thermal extremes than adults (Teli et al., 2012; Falk and Dotan, 2008) — and reinforces the case for framing indoor environmental quality in school buildings as an environmental health concern rather than a structural one.

6. BEYOND THE BLOCK: INTERDISCIPLINARY SYNTHESIS

Building material selection extends beyond structural performance to function as a determinant of indoor environmental quality and pupil well-being. In naturally ventilated school buildings, envelope systems operate as passive environmental regulators, influencing thermal exposure, physiological stress, and learning conditions.

In this context, ICEB is not only a construction alternative but part of a broader environmental health and educational performance system. Material choice therefore becomes a coupled decision linking architecture, public health, learning outcomes, and educational infrastructure in resource-constrained tropical environments.

7. CONCLUSIONS AND POLICY IMPLICATIONS

This study demonstrates that ICEB construction provides a statistically significant and practically meaningful indoor thermal advantage over conventional SCB systems in naturally ventilated primary schools in hot-humid Nigeria. The 2.03°C mean temperature reduction, corroborated by consistent occupant perception improvements across $n = 257$ pupils at six paired schools, establishes building material choice as a primary determinant of indoor environmental quality and pupil well-being.

Building material selection should be formally recognised as a passive environmental performance variable within Universal Basic Education Commission (UBEC) guidelines for classroom design. ICEB presents a viable, low-carbon alternative to SCB in contexts where energy poverty excludes mechanical cooling, and its use of locally sourced materials aligns school construction with circular economy principles and climate adaptation objectives for South East Nigeria.

The findings are bounded by their focus on a single climatic region and a wet-season monitoring campaign. Seasonal performance across the harmattan dry season warrants further investigation. Nevertheless, the evidence supports integration of performance-based material criteria into school construction standards as a measured and evidence-grounded step toward healthier, more equitable learning environments.

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