UAR Journal of Multidisciplinary Studies (UARJMS)
ISSN: 3049-4346 (Online)
Journal Home Page
Volume- I Issue- 4 (June) 2025
Frequency: Monthly

Case Studies
Received: 18.06.2025 | Accepted: 22.06.2025 | Published: 24.06.2025

Assessment of In-Situ Concrete Strength and Soil Bearing Capacity for the Redevelopment of an Abandoned RC Building in Plateau State, Nigeria

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Abstract
This study assessed the structural integrity of an abandoned one-storey reinforced concrete building in Tudun Wada, Jos North, Plateau State, Nigeria, proposed for redevelopment as a filling station and office complex. Non-destructive testing using the Schmidt Rebound Hammer was conducted on slabs, beams, and columns, with results indicating that most concrete elements exceeded the standard compressive strength of 25 N/mm². Visual inspections revealed significant structural deficiencies, including the absence of four external load-bearing columns, replaced by degraded hollow blocks, compromising structural stability. Geotechnical analysis of soil samples collected at 1.5 m depth showed safe bearing capacities ranging from 213.6 to 275.5 kN/m², confirming the adequacy of foundation support. While the concrete quality and subsoil conditions were generally satisfactory, the building's compromised structural configuration demands urgent remedial engineering intervention. The study recommends strict adherence to construction standards, enhanced supervision, and the use of combined testing methods for reliable integrity assessments and future redevelopment decisions.

Keywords: Structural integrity, Compressive strength, (NDT), Geotechnical analysis, Bearing capacity, Reinforced concrete structure.

1. INTRODUCTION

Evaluating the properties of existing structures to assess their performance and safety is a critical aspect of engineering practice. A key parameter in reinforced concrete design is the compressive strength of concrete, which directly influences structural capacity and resilience [1]. Traditionally, this strength is determined through laboratory testing of cast concrete cubes or by extracting core specimens from in-situ concrete [2]. However, both methods have drawbacks lab cubes may not reflect field conditions, while core drilling can damage structural stability [3].

To overcome these limitations, Non-Destructive Testing (NDT) methods have become essential tools for assessing structural integrity. NDT enables rapid, in-situ evaluation of concrete elements such as buildings, bridges, and foundations without compromising their integrity [4-6, 15]. Tests like the Rebound Hammer Test (RHT) and Ultrasonic Pulse Velocity (UPV) are widely used for quality control, durability assessment, and problem detection in concrete [6].

The Schmidt Rebound Hammer Test, in particular, measures surface rebound hardness to estimate compressive strength and evaluate concrete uniformity. Recent studies have reinforced its efficacy such as a Nigerian field case study where rebound hammer results were effectively correlated to as-built column strength [7]. Experimental research has produced strong statistical relationships between rebound number and compressive strength, even in eco-concrete blends [8]. Structural integrity assessments typically involve visual inspections, displacement measurements, crack mapping, and vibration monitoring to detect distress and failure risks [9]. Combining multiple NDT methods improves result reliability, as each method has inherent limitations [10].

This study focuses on the structural integrity assessment of an abandoned one-storey reinforced concrete structure at Tudun Wada, Jos North, Plateau State, Nigeria recently propose for a filling station/office complex. Prolonged exposure to environmental elements and periods of neglect necessitate an evaluation of concrete quality and load-bearing capacity. The investigation employs the Schmidt Rebound Hammer Test, supported by field observations, to derive insights into the structural soundness and potential for reuse of the building.

2. Materials and Methods

2.1 Materials

The primary non-destructive testing (NDT) equipment employed for this study was the Schmidt Rebound Hammer (Model: C386N, Matest Digital Concrete Test Hammer), compliant with EN 12504-2 specifications. This device, originally developed in 1948 by Ernst Schmidt, is widely used for assessing the surface hardness and estimating the compressive strength of concrete.

To assess crack widths and propagation patterns in the structure, Vernier calipers were utilized for precise linear measurements. Additionally, manual excavation tools, including diggers and shovels, were employed to access subsoil samples beneath the foundation level at approximately 1.5 meters depth for geotechnical evaluation as shown in Figures 1, 2 and 3.

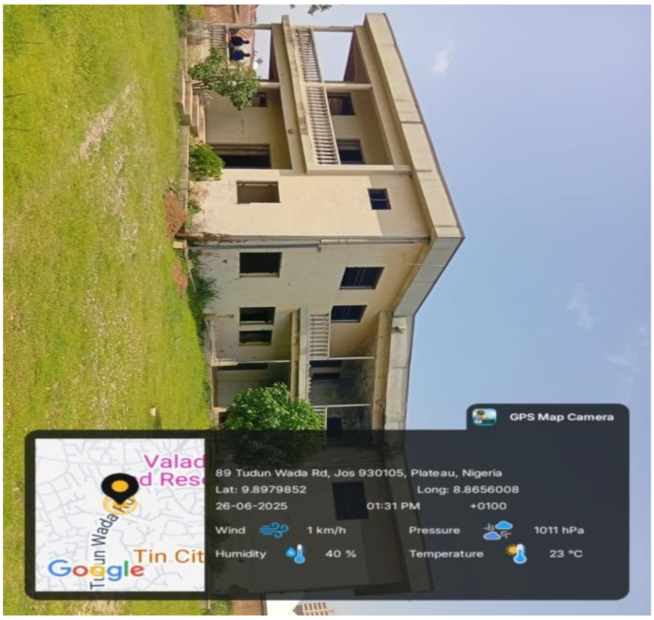

Figure 1: Partial View of the Existing Structure (Front Elevation)

2.2 Methods

2.2.1 Rebound Hammer Testing

The Schmidt Rebound Hammer operates on the principle of measuring the rebound of a spring-loaded steel mass impacting a concrete surface. The rebound distance is correlated to surface hardness, which in turn provides an estimate of the concrete's compressive strength. Testing was conducted in accordance with ASTM C805 [13]. For each test location on the structural elements (walls and columns), ten (10) individual rebound readings were taken and averaged to minimize anomalies due to surface irregularities. The data were then interpreted using manufacturer-supplied correlation charts and standard concrete quality classifications.

2.2.2 Crack Mapping and Visual Inspection

Detailed visual inspections were conducted to identify signs of deterioration, including surface cracks, spalling, efflorescence, and joint separations. Measured crack widths were categorized and recorded. Observations focused on areas with omitted structural members and degraded blockwork, especially at known high-stress zones.

2.2.3 Soil Sampling and Laboratory Analysis

Disturbed soil samples were collected from beneath the foundation of each structural block (labeled A, B, C, D and E). Samples were sealed in airtight bags and transported to the geotechnical laboratory for analysis. Direct shear box testing, conforming to BS 1377 [14] was employed to determine the shear strength parameters of the soil (cohesion C, and angle of internal friction Ø). Each sample was tested under three different vertical loads, and the corresponding maximum shear stresses were recorded.

Figure 2: Excavation of the Foundation

Figure 3: Schmidt Rebound Harmer on an Element

2.2.4 Bearing Capacity Estimation

Using the shear strength parameters obtained from laboratory tests, the ultimate bearing capacity of the soil was computed using Terzaghi's bearing capacity equation as shown in Equation 1.

$$q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma \quad (1)$$

Where:

q_u = ultimate bearing capacity (kN/m²)

c = soil cohesion (kN/m²)

γ = unit weight of soil (kN/m³)

D_f = foundation depth (m)

B= foundation width (m)

N_c, N_q, N_γ= bearing capacity factors, based on internal friction angle ∅

These parameters facilitated the evaluation of the structural foundation's suitability for future reuse or redevelopment.

3. Results and Discussion

3.1 Assessment of Concrete Strength Using Rebound Hammer.

Results of Non Destructive Strength assessment of columns, beams and slabs using Schmidt Hammer tests are summarized in Table 1:

Table 1: Schmidt Rebound Hammer Test Result on Selected Elements

Element	Element ID	Rebound Value	Average rebound Value	Compressive Strength (N/mm²)	Remark
SLAB	S_1	32, 26, 34, 26, 20, 30, 32, 26, 24, 26	27.6	38.20	*High strength concrete*
	S_2	18, 26, 16, 18, 20, 16, 18, 28, 26, 18	20.4	26.64	*Good quality concrete*
BEAM	B_1	26, 28, 20, 26, 30, 30, 30, 30, 34, 26	28.0	30.00	*High strength concrete*
	B_2	24, 26, 24, 28, 30, 24, 20, 32, 26, 28	26.2	35.92	*High strength concrete*
COLUMN (External)	C_1	26, 26, 24, 24, 26, 20, 26, 20, 22, 26	24.0	32.40	*High strength concrete*
	C_2	18, 18, 20, 20, 24, 20, 18, 18, 20, 20	19.6	25.36	*Good quality concrete*
	C_3	24, 26, 26, 24, 24, 20, 26, 24, 26, 26	24.6	33.36	*High strength concrete*
	C_4	20, 24, 20, 20, 20, 24, 20, 24, 20, 24	21.6	28.56	*Good quality concrete*
	C_5	20, 24, 26, 20, 26, 30, 24, 24, 20, 24	23.8	32.08	*High strength concrete*
	C_6	20, 18, 20, 22, 18, 20, 24, 20, 18, 20	20.0	26.00	*Good quality concrete*
	C_7	26, 26, 24, 20, 26, 30, 24, 26, 24, 26	25.2	34.32	*High strength concrete*
COLUMN (Internal)	C_8	18, 20, 26, 20, 26, 20, 20, 20, 26, 24	22.0	29.20	*Good quality concrete*
	C_9	28, 20, 24, 20, 26, 24, 20, 24, 20, 26	23.2	31.12	*High strength concrete*

The Schmidt Rebound Hammer test results indicate that most concrete elements on structure exhibit satisfactory compressive strength values above the 25 N/mm² standard, suggesting adequate material integrity under current conditions. However, critical structural issues were observed on-site, including the absence of four external load-bearing columns, which were inappropriately replaced with deteriorating hollow concrete blocks. This deviation severely undermines the building's load-bearing capacity and stability, especially in areas near Slab S2 and Column C2, which showed marginal compressive strength values just above the minimum threshold. While the foundation dimensions are generally compliant, the lack of structural continuity due to missing columns and degraded blockwork poses significant safety risks and demands urgent corrective action.

3.2 Foundation Bearing Capacity

The Results of the ultimate and safe bearing capacity of the soil are presented in Table 2

Table 2: Soil Bearing Capacity Values

S/N	Sampling Point	$Q_{ultimate}$ (kN/m^2)	Q_{safe} (kN/m^2)
1	A@1.5m	688.7	275.5
2	B@1.5m	637.2	254.9
3	C@1.5m	533.9	213.6
4	D@1.5m	535.0	214.0
5	E@1.5m	562.6	225.0

The results of soil samples taken at 1.5 meters depth from five sampling points revealed safe bearing capacities ranging from 213.6 kN/m² to 275.5 kN/m². These values exceed the assumed allowable bearing capacity of 200 kN/m² used in foundation design, indicating that the soil in the area is satisfactory for supporting structural loads. This confirms that the existing and proposed foundation base sizes are adequate and safe, with no immediate need for soil improvement or deep foundation systems for the intended structural modifications.

4.0 Conclusion

This study assessed the structural integrity of an abandoned one-storey reinforced concrete building in Tudun Wada, Jos North, using the Schmidt Rebound Hammer Test and geotechnical analysis. The majority of concrete elements demonstrated compressive strengths above the standard 25 N/mm², indicating satisfactory in-situ material performance. Similarly, the soil's safe bearing capacity exceeded 200 kN/m², confirming its adequacy for structural support. However, field inspections revealed critical deficiencies, particularly the omission of four external load-bearing columns, replaced by deteriorating hollow blocks, which severely compromise the building's structural continuity and stability. While the concrete quality and foundation conditions support reuse, the compromised structural configuration necessitates immediate engineering intervention to restore load-bearing integrity and ensure the building's safety for redevelopment as a filling station and office complex.

It is recommended that future redevelopment projects place strong emphasis on proper quality control measures, strict adherence to construction standards, and effective supervision to prevent avoidable structural deficiencies and ensure the structure performs as intended. Additionally, the study advocates for the use of a combination of testing methods, rather than relying on a single test, as this approach yields more reliable and comprehensive results for making informed decisions about the acceptance or rejection of the structure or its individual components for future use.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Conceptualization - Annune Jighjigh Eric, Abdulahi Aliyu; **Data curation** - Annune Jighjigh Eric; **Formal analysis** - Annune Jighjigh Eric, Abdulahi Aliyu; **Investigation** - Annune Jighjigh Eric; **Methodology** - Annune Jighjigh Eric, Abdulahi Aliyu; **Project administration** - Annune Jighjigh Eric; **Resources** - Abdulahi Aliyu; **Software** - Annune Jighjigh Eric; **Supervision** - Abdulahi Aliyu; **Validation** - Abdulahi Aliyu; **Visualization** - Annune Jighjigh Eric; **Roles/Writing – original draft** - nnune Jighjigh Eric; **Writing – review & editing** - Abdulahi Aliyu, Annune Jighjigh Eric.

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