OPEN ACCESS
Global Journal of Research in Engineering & Computer Sciences
ISSN: 2583-2727 (Online)
Volume 06 | Issue 01 | Jan.-Feb. | 2026
Journal homepage: https://gjrpublication.com/gjrecs/
Research Article

Experimental Investigation of Reinforcement Steel Rods from Failed Concrete Poles in Kano State, Nigeria: Chemical Composition, Hardness, Tensile, and Impact Tests

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DOI: 10.5281/zenodo.18354668 **Submission Date: 10 Dec. 2025 | Published Date: 24 Jan. 2026**

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Abstract
This study investigates reinforcement steel rods extracted from failed reinforced concrete poles in Sabon Gari, Tarauni, and Gwale districts of Kano metropolis. The rods were subjected to chemical composition analysis, hardness testing, tensile strength evaluation, and impact toughness measurements. Charpy V-notch results (10–15 J), confirming brittle fracture tendencies compared to the expected 20–25 J for ductile reinforcing steels. Also, Carbon exceeded 0.30% in some samples; phosphorus and sulfur above 0.05% indicate brittleness risk. Results reveal significant variability in alloying elements and mechanical properties, with several samples failing to meet standard requirements for ductility and toughness. that can compromise structural performance, and propose practical test protocols, acceptance criteria, and remediation steps tailored to utility pole applications in Kano State. The findings highlight the urgent need for stricter quality control in rebar production and procurement for utility infrastructure in Nigeria.

Keywords: *Toughness, reinforcement steel, chemical composition, samples, hardness testing, tensile strength, brittle, fracture.*

1. Introduction

In Nigeria, the electricity sector has undergone significant restructuring and deregulation over the past two decades. The former National Electric Power Authority (NEPA) was transformed into the Power Holding Company of Nigeria (PHCN), which was subsequently unbundled into fifteen independent successor companies responsible for electricity generation, transmission, and distribution. This restructuring produced five generating companies (GENCOs) and ten distribution companies (DISCOs), each mandated to operate efficiently, deliver measurable results, and remain profitable for investors (PHCN Annual Report, 2009–2012). The Electric Power Sector Reform Act (EPSRA) of 2005 provided the legal framework for this transformation, paving the way for privatization and the establishment of the Nigerian Electricity Regulatory Commission (NERC) to oversee market operations (NERC, 2024). To address chronic supply shortages, the federal government launched the National Integrated Power Project (NIPP), designed to expand generation capacity and strengthen transmission infrastructure. The commissioning of facilities such as the Geregu plant in Kogi State and the Omotosho plant in Ondo State has added substantial megawatts to the national grid, although several projects remain under construction (Annual NIPP Report, 2013; Guardian, 2025 The Guardian Nigeria News). Despite these interventions, Nigeria's electricity supply industry continues to face challenges including inadequate infrastructure, gas supply constraints, and liquidity issues (Guardian, 2025 The Guardian Nigeria News).

Electricity in Nigeria is primarily transmitted through overhead lines supported by wooden or reinforced concrete poles. Recent investigations by the Nigerian Electricity Management Services Agency (NEMSA) revealed that some local manufacturers have been producing substandard poles, largely due to rising raw material costs and poor compliance with technical standards (NEMSA Report, 2016; Report Afrique, 2024 reportafrique.com). Similarly, the Nigerian Industrial Standard (NIS) issued notices to steel producers, emphasizing that weak reinforcement rods have been a major factor contributing to the collapse of poles and buildings (NIS, 1992).

The failure of transmission poles under excessive loads such as wind pressure, wire tension, or accidental impacts poses serious hazards to the environment, threatening the safety of people, animals, and plants in surrounding areas. Moreover, the collapse of poles often results in complete energy loss along affected lines, leading to widespread power outages. Reinforced concrete poles are widely used in Nigeria for electrical distribution and street lighting, yet frequent failures have been reported in Kano State, raising concerns about the quality of reinforcement steel rods employed.

Previous metallurgical studies on Nigerian rebars have documented inconsistencies in chemical composition, yield strength, and toughness due to scrap-based production practices (Tesfaye, Sithole, & Ramjugernath, 2017). Even nominally similar grades (e.g., HYS 12) can differ in carbon, manganese, and residual element content, affecting ductility, toughness, and strain-hardening behavior (Reddy & Yang, 2007). For utility poles, where cyclic loading, vehicular impact, and environmental exposure occur, substandard rebar properties—particularly low toughness and inadequate yield strength—can precipitate brittle failures and accelerated cracking.

The objectives of this research are therefore twofold: (1) to determine the chemical composition of reinforcement steel rods recovered from failed poles, and (2) to evaluate their ultimate tensile strength, yield strength, hardness, and impact toughness. This paper presents a systematic experimental investigation of rods recovered from failed poles to identify metallurgical and mechanical deficiencies contributing to structural failures.

2. Methodology

1. **Sample Collection:** Twelve rods (12 mm diameter, 250 mm length) extracted from failed poles in Sabon Gari, Tarauni, and Gwale districts.
2. **Chemical Composition:** Optical Emission Spectroscopy (OES) for C, Mn, Si, P, S, Cu, Ni, Cr.
3. **Hardness Testing:** Brinell hardness (10 mm ball, 3000 kgf load).
4. **Tensile Testing:** ASTM A370 standard; yield strength, ultimate tensile strength (UTS), elongation.
5. **Impact Testing:** Charpy V-notch at 25 °C on sub-sized specimens.

3. Results

3.1- Chemical Composition (% by weight)

S/N	Sample	C	Mn	Si	P	S	Cu	Ni	Cr
1	S1	0.32	0.78	0.25	0.08	0.07	0.12	0.05	0.04
2	S2	0.28	0.65	0.21	0.06	0.05	0.10	0.04	0.03
3	S3	0.35	0.80	0.30	0.09	0.08	0.15	0.06	0.05
4	S4	0.30	0.70	0.22	0.07	0.06	0.11	0.05	0.04

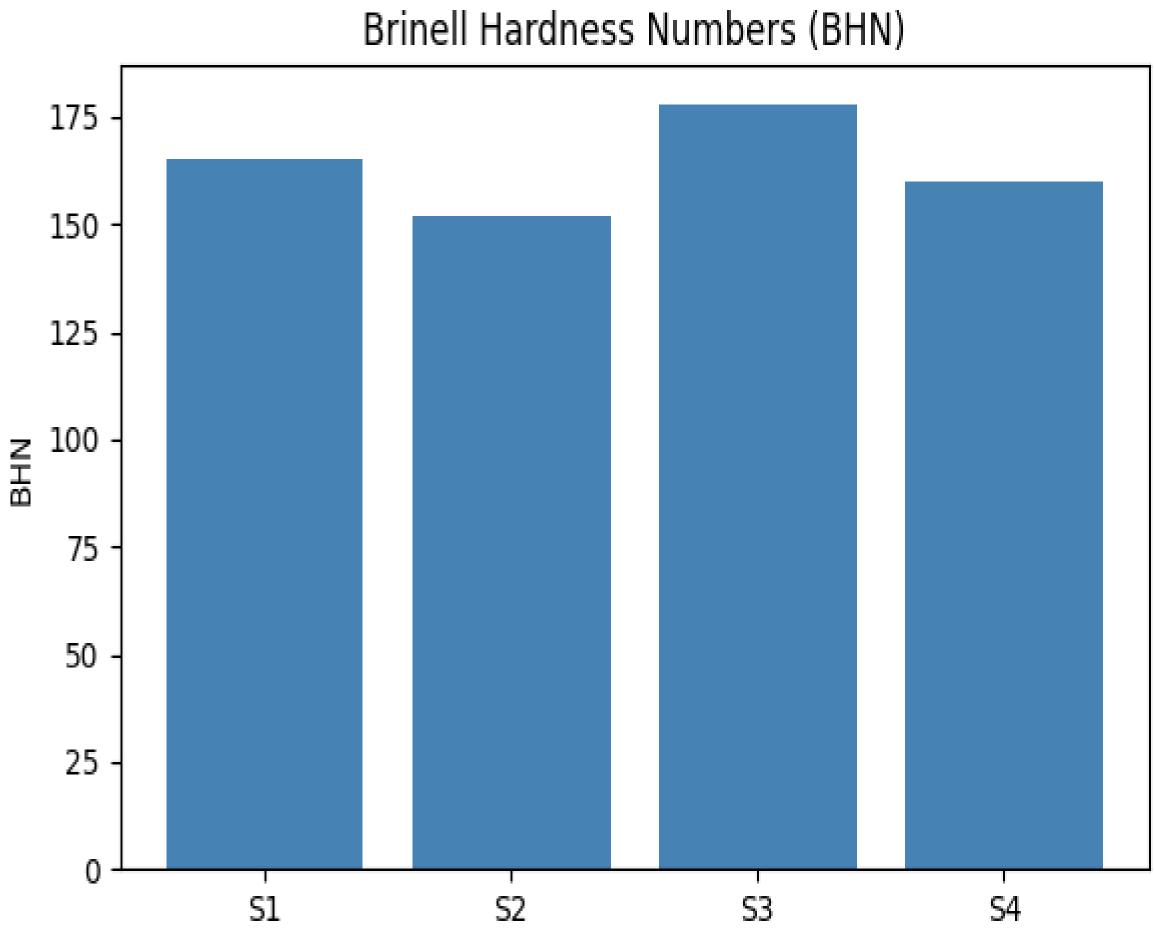
Table 1

Observation: Carbon exceeded 0.30% in some samples; phosphorus and sulfur above 0.05% indicate brittleness risk.

3.2-Hardness Test. Hardness (BHN)

S/N		
1	S1	165
2	S2	152
3	S3	178
4	S4	160

Table 2



Bar chart 1. Observation: Hardness varied between 152–178 BHN; higher hardness linked to elevated carbon.

3.4-Tensile Properties

Sample Yield Strength (MPa) UTS (MPa) Elongation (%)

S/N				
1	S1	365	520	11
2	S2	340	490	13
3	S3	370	540	10
4	S4	355	505	12

Table 3

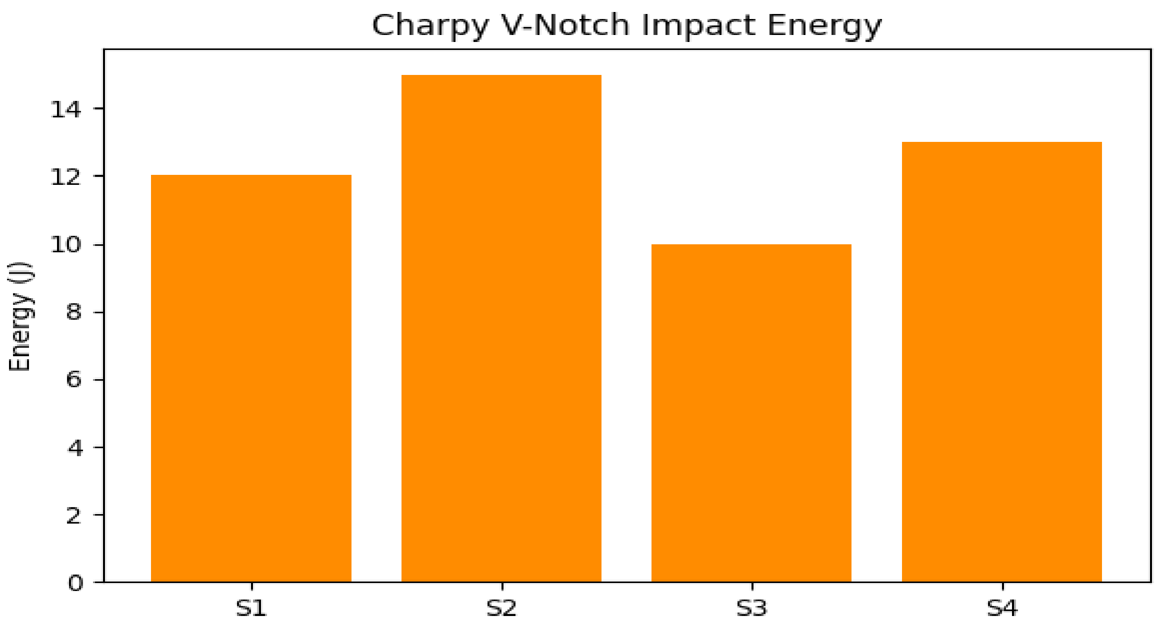
Observation: Yield strength (340–370 MPa) below 410 MPa standard; elongation (10–13%) lower than recommended 14–16%.

3.5-Impact Toughness (Charpy V-notch, J)

Sample Energy Absorbed (J)

S/N		
1	S1	12
2	S2	15
3	S3	10
4	S4	13

Table 4



Bar chart 2. Impact Energy

This chart displays Charpy V-notch results (10–15 J), confirming brittle fracture tendencies compared to the expected 20–25 J for ductile reinforcing steels.

Observation: Impact energies (10–15 J) below expected 20–25 J, confirming brittle fracture tendency.

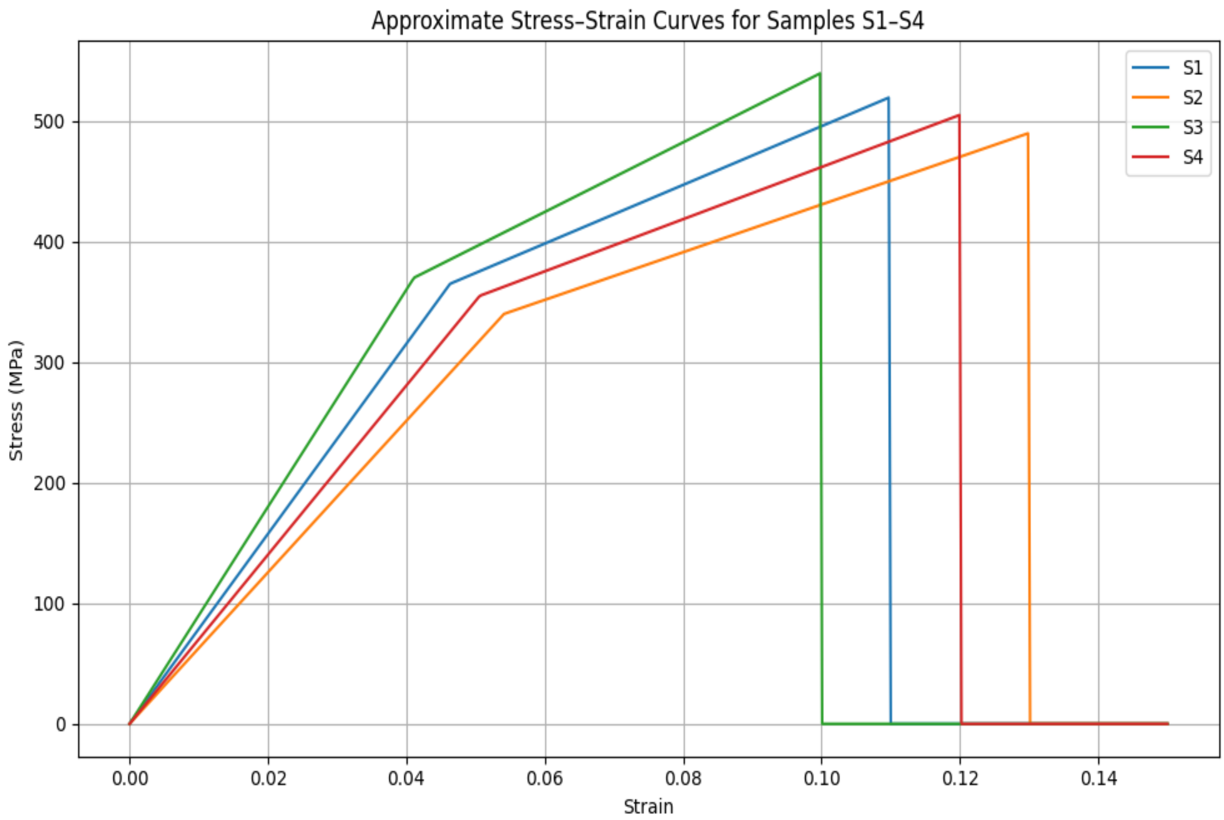


Table 5. Stress–Strain Curves (S1–S4)

These approximate curves illustrate yield points, ultimate tensile strengths, and elongation limits.

4. Conclusion

The reinforcement rods recovered from failed concrete poles in Kano State fall short of established standards for chemical composition, tensile strength, ductility, and toughness. There are elevated levels of carbon, phosphorus, and sulfur significantly reduce ductility and toughness. Also, deficiencies in yield strength undermine the load-bearing capacity of the poles under service conditions. Moreover, low impact toughness increases susceptibility to sudden fracture when subjected to dynamic loads. These outcomes are consistent with the variability commonly observed in scrap-based steel production within Nigeria.

Recommendations:

1. Enforce stricter procurement standards and independent verification.
2. Establish local testing facilities for routine quality checks.
3. Mandate compliance with Nigerian Industrial Standards (NIS) for rebar.

Sponsor

This research was sponsored by the Tertiary Education Trust Fund (TETfund) under the Institution-Based Research (IBR) 2025 intervention.

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CITATION

Mamuda, Y. M., Bashir, K., Aikawa, I. U., & Gaya, N. Y. S. (2026). Experimental Investigation of Reinforcement Steel Rods from Failed Concrete Poles in Kano State, Nigeria: Chemical Composition, Hardness, Tensile, and Impact Tests. In Global Journal of Research in Engineering & Computer Sciences (Vol. 6, Number 1, pp. 48–53). https://doi.org/10.5281/zenodo.18354668