

Comparative Evaluation of 2.5-ton CPT, 10-ton CPT and SPT for Bearing Capacity Estimation in Swampy Tropical Soils of Akure, Southwestern Nigeria

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International Journal of Science and Research Archive, 2026, 19(01), 872-883

Publication history: Received on 09 March 2026; revised on 19 April 2026; accepted on 22 April 2026

Article DOI: <https://doi.org/10.30574/ijrsra.2026.19.1.0809>

Abstract

Reliable estimation of foundation bearing capacity in swampy tropical soils is challenging due to weak, highly compressible and heterogeneous ground conditions. This study presents a comparative evaluation of bearing capacity estimates derived from 2.5-ton CPT, 10-ton CPT and Standard Penetration Test (SPT) data from lowland sites in Akure, southwestern Nigeria, underlain by weathered basement complex and transported soft soils. Cone tip resistance, sleeve friction and SPT N-values were analysed within a consistent depth framework, and bearing capacities were estimated using established empirical correlations. The results show a clear increase in soil resistance and bearing capacity with depth across all methods. However, systematic differences were observed in the magnitude of the estimates. The 2.5-ton CPT reached refusal in deeper, stiffer layers and generally produced more conservative values, whereas the 10-ton CPT provided continuous, higher-resolution profiles. The SPT yielded significantly higher bearing capacity values in intermediate and deeper layers, suggesting potential overestimation when used alone. The study highlights the strong influence of test method and equipment capacity on design outcomes and emphasises the need for site-specific calibration and combined use of in-situ tests in tropical lowland environments.

Keywords: Bearing capacity; Foundations; Groundwater; In situ Testing; Site Investigation

List of notations

- q_c is cone tip resistance (kN/m^2 or MPa)
- f_s is sleeve friction from CPT (kN/m^2 or MPa)
- N is measured SPT blow count
- N_{60} is corrected SPT blow count normalised to 60% hammer energy
- q_u is the ultimate bearing capacity of soil (kN/m^2)
- q_a is the allowable bearing capacity of soil (kN/m^2)
- k is an empirical factor depending on soil type
- c is cohesion or undrained shear strength parameter (kN/m^2)
- α is an empirical correlation factor (-)
- ϕ is the effective angle of internal friction of soil (degrees)
- γ is the unit weight of soil (kN/m^3)
- B is the foundation width (m)
- D_f is the depth of foundation embedment (m)
- FS is the factor of safety (-)
- N_q, N_y, N_c bearing capacity factors (-)

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1 Introduction

Reliable estimation of foundation bearing capacity is a fundamental requirement in geotechnical engineering practice, particularly in areas underlain by weak, compressible or highly variable soils. In tropical regions, intense chemical weathering, high groundwater levels, and the frequent presence of organic or soft clay layers often produce soil profiles with low strength and high compressibility, which pose significant challenges for safe and economical foundation design [19, 9]. In lowland and swampy environments, these challenges are further amplified by seasonal water-level fluctuations and heterogeneous stratification, thereby increasing the risk of excessive settlement or bearing failure if subsurface conditions are not adequately characterised [1].

In situ testing methods remain the backbone of site investigation practice for such difficult ground conditions. Among these, the Standard Penetration Test (SPT) and the Cone Penetration Test (CPT) are the most widely used due to their relative simplicity, cost-effectiveness and extensive empirical background. The CPT, in particular, provides continuous profiles of cone tip resistance and sleeve friction with depth, enabling detailed stratigraphic identification and estimation of key engineering parameters [13, 9]. The SPT, although more discontinuous, is still widely used in many parts of the world and remains a common basis for preliminary design correlations in routine practice [10, 14].

Over the past decade, significant efforts have been made to refine CPT-based interpretation frameworks and improve the reliability of correlations for soil classification and design parameters [13, 14, 9]. Similarly, SPT-based methods continue to be used, often supported by energy corrections and empirical adjustments to improve consistency [10]. Despite these advances, most widely used correlations for estimating bearing capacity from CPT and SPT data were developed primarily from databases dominated by temperate, alluvial or relatively uniform soil deposits. Their direct application to tropical residual soils or swampy lowland deposits, which commonly exhibit complex fabric, variable mineralogy and partial cementation or organic content, remains uncertain.

In tropical basement complex terrains, such as those found in southwestern Nigeria, weathering processes often produce a highly variable vertical profile, typically consisting of near-surface organic or soft clayey materials underlain by progressively stiffer clayey sands, silty sands and residual soils derived from crystalline rocks [12]. These materials do not always conform to the assumptions underlying many conventional CPT- and SPT-based design correlations. Recent studies have emphasised that soil behaviour in tropical environments may deviate significantly from that of sedimentary deposits, leading to potential over- or under-estimation of strength and bearing capacity if global correlations are applied without local evaluation [9, 14].

Another practical issue that has received limited attention in the literature is the influence of CPT equipment capacity on measured cone resistance and derived design parameters, particularly in heterogeneous or partially cemented tropical soils. In practice, both low-capacity and higher-capacity CPT systems are used, especially in developing regions, depending on equipment availability and site accessibility. However, the extent to which results obtained from, for example, a 2.5-ton CPT system and a 10-ton CPT system are directly comparable in weak to moderately stiff tropical soils is not well documented. Differences in achievable penetration depth, mobilised resistance, and data quality may lead to systematic differences in interpreted bearing capacity, with important implications for design reliability.

In Nigeria, and specifically in the Akure area of southwestern Nigeria, swampy and lowland terrain is increasingly being developed for residential and infrastructure projects. The area is underlain by Precambrian Basement Complex rocks and characterised by deeply weathered profiles and locally waterlogged ground conditions [3]. While CPT and SPT are routinely used in site investigations within this region, there is a lack of published studies that (i) directly compare results from different CPT capacities and (ii) evaluate their bearing capacity predictions alongside those obtained from SPT data within the same geological and hydrogeological setting.

The problem addressed in this study is therefore the uncertainty associated with applying standard CPT- and SPT-based bearing capacity correlations, as well as with using CPT capacities from different tests, to swampy tropical soils without site-specific evaluation. This uncertainty may lead to unsafe designs if bearing capacity is overestimated, or to overly conservative and uneconomical solutions if it is underestimated.

This study aims to conduct a comparative evaluation of bearing capacity estimates derived from 2.5-ton CPT, 10-ton CPT, and SPT data in swampy tropical soils in Akure, southwestern Nigeria. The specific objectives are to: (i) analyse and compare cone resistance and sleeve friction profiles obtained from the two CPT systems; (ii) estimate bearing capacity using established CPT- and SPT-based methods under consistent foundation assumptions; and (iii) assess the level of agreement and divergence between the methods with reference to the local soil conditions. By doing so, the

study seeks to provide site-specific evidence on the influence of CPT capacity and testing method on bearing capacity estimation in tropical lowland environments, and to offer practical guidance for foundation design in similar settings.

2 Site Description and Ground Conditions

2.1 Location and setting

The study area is located in Akure, the capital city of Ondo State in southwestern Nigeria (Figure 1). Akure lies within the humid tropical climatic zone and is characterised by relatively high annual rainfall and elevated groundwater levels, conditions that promote the development of swampy and lowland terrains in several parts of the city and its surroundings [4]. The investigation sites are situated in low-lying areas where surface water accumulation and shallow groundwater are common, especially during the rainy season. These environmental conditions make the area representative of many tropical lowland settings in southwestern Nigeria, where weak and saturated near-surface soils strongly influence foundation performance.

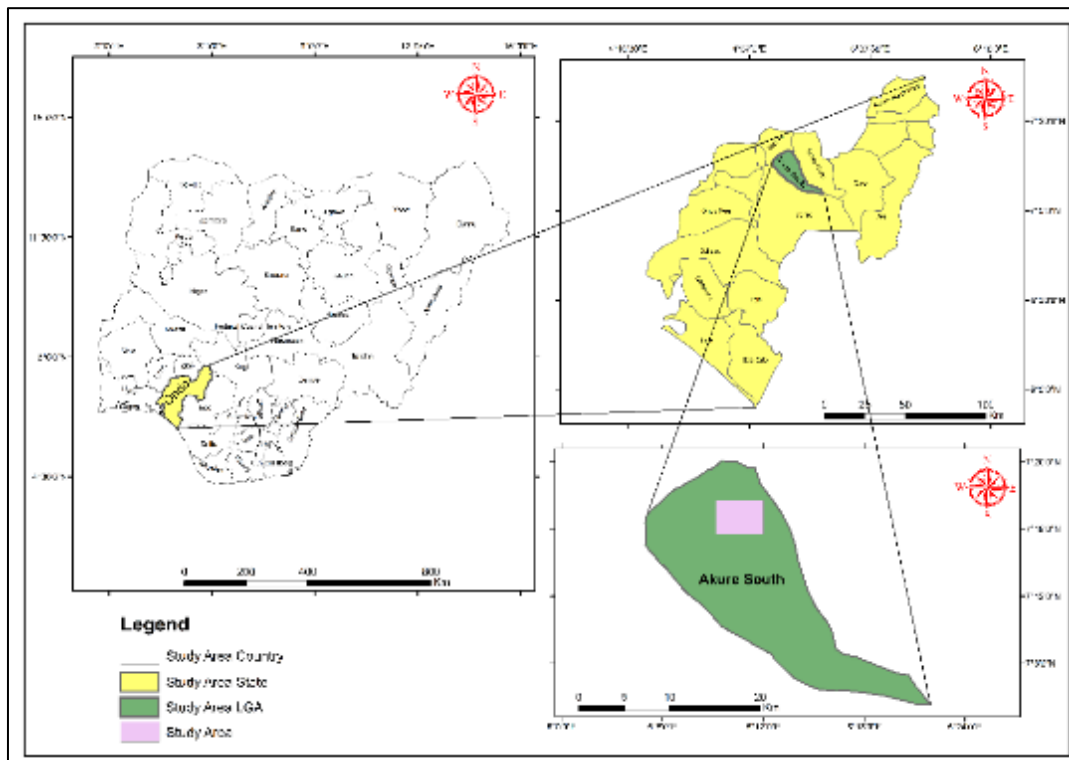


Figure 1 Location of study area

2.2 General geological setting

Akure, located in southwestern Nigeria, is underlain by Precambrian Basement Complex rocks, dominated by migmatite–gneiss, charnockitic, and granitic units, alongside subordinate quartzites and schists [2]. In the lowland and swampy portions of the area, the near-surface soils are primarily transported and reworked materials, deposited under low-energy conditions, rather than purely residual in origin [7]. These deposits exhibit strong vertical and lateral variability over short distances, which has important implications for site characterisation and foundation design [9, 14].

2.2.1 Typical soil profile and engineering characteristics

The subsurface conditions revealed by the field investigation indicate a relatively consistent two-layered to multi-layered profile across the study sites. The uppermost layer generally consists of soft to very soft organic clay or organic silty clay, extending from the ground surface to depths typically of the order of about 0.5–1.5 m, although local variations occur. This layer is highly compressible, exhibits low shear strength, and is strongly influenced by groundwater conditions. Beneath the organic surface layer, the soils commonly grade into clayey sands and silty sands, which are

interpreted as transported and reworked materials rather than purely residual products of in-situ weathering. These underlying layers show increasing stiffness with depth but remain heterogeneous in terms of composition and strength.

The presence of transported soils overlying or interlayered with weathered basement-derived materials results in soil profiles that do not always conform to idealised residual soil models commonly assumed in tropical regions. Such stratigraphic complexity is expected to influence both CPT and SPT responses, particularly in the transition zones between the organic clays and the sandier layers, and therefore has direct relevance to the interpretation of in-situ test data and the estimation of bearing capacity [13, 9].

2.2.2 Groundwater conditions

Groundwater was encountered at shallow depths across the investigated sites, consistent with the swampy and lowland nature of the area. In several locations, the groundwater table was observed at or near the ground surface during the period of investigation, while in others it occurred within the upper organic clay layer. Such shallow groundwater conditions are typical of low-lying terrain in Akure and contribute significantly to low effective stress and reduced shear strength in near-surface soils [6]. The high degree of saturation is therefore expected to affect both the measured in-situ test parameters and the derived bearing capacity estimates, particularly for shallow foundations, and must be taken into account when interpreting CPT and SPT results [10, 14].

3 Materials and Methods

3.1 Field Testing Programme

The field investigation comprised in situ cone penetration tests (CPT) and standard penetration tests (SPT) conducted at multiple locations within swampy lowland sites in Akure, southwestern Nigeria. In total, nine (9) CPT soundings were conducted using a 10-ton capacity CPT system, and sixteen (16) CPT soundings were carried out using a 2.5-ton capacity CPT system. The 10-ton CPT unit provided both cone tip resistance (q_c) and sleeve friction (f_s) measurements, whereas the 2.5-ton CPT recorded cone tip resistance (q_c) only due to equipment configuration limitations. These in-situ tests were conducted to profile the subsurface soil resistance with depth continuously and to form the basis for bearing capacity estimation.

In addition to CPT soundings, sixteen (16) SPT boreholes were drilled to obtain SPT N-values and disturbed soil samples for classification. The SPT was performed in accordance with widely accepted testing practice, with the sampler advanced to obtain penetration resistance over a depth interval of 0.3 m (300 mm) at each station. The number of hammer blows required to achieve penetration, referred to as the N-value, was recorded at each depth interval. The SPT procedure conforms to recognised international testing standards, such as [5] (Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils), and is widely used to infer soil density and strength parameters (Standard Penetration Test procedure; [5]).

The spatial distribution of CPT and SPT points was planned to enable meaningful comparisons of results from different testing methods under similar ground conditions. Field operations were undertaken by trained personnel, with attention to maintaining the verticality of the CPT push rods and to consistent SPT hammer operation to ensure data integrity, consistent with best practice in in-situ testing [10, 14].

3.2 Measured Parameters

The primary parameters measured in the field investigation were:

Cone tip resistance (q_c) with depth from both 10-ton and 2.5-ton CPT soundings. Cone tip resistance is a measure of the soil's resistance to penetration and is sensitive to changes in soil type, density, and strength [13].

Sleeve friction (f_s) with depth from the 10-ton CPT soundings, providing direct information on soil frictional resistance.

SPT N-values from the boreholes, representing dynamic penetration resistance as a function of depth. The N-value is a widely used index for estimating relative density and strength of soils, particularly in cohesionless and mixed soils (standard penetration test procedure; [5]).

These parameters were plotted against depth for each test location to visualise resistance profiles and support stratigraphic interpretation. The q_c and f_s profiles from CPT were used to identify soil layering and assess variation in

resistance properties with depth, while N-value profiles provided a complementary view of subsurface resistance from a dynamic penetration perspective.

3.3 Data Processing and Interpretation

Data from the CPT and SPT tests were processed in their measured form without extensive laboratory calibration corrections. The CPT q_c and f_s values were used directly in interpretation, consistent with common practice in comparative CPT studies where relative resistance profiles are the focus [13]. The SPT N-values were recorded and used in their uncorrected form for comparative purposes; where needed, corrections such as hammer energy-efficiency adjustments (e.g., to standardised N60) may be considered in more detailed design work, but were not central to the methodological comparison herein.

To enable comparison across testing methods, CPT and SPT results were analysed within a common depth framework. Where test locations were not exactly coincident, nearby soundings within the same soil unit were paired under the assumption of reasonable lateral continuity of stratigraphy over short distances (consistent with conventional site investigation practice). Soil layers were identified through consistent trends in resistance values, using marked changes in q_c and f_s for CPT and changes in N-values for SPT to delineate transitions between the soft organic surficial soils and the underlying sandier materials.

3.4 Bearing Capacity Estimation Framework

Bearing capacity was estimated independently using CPT and SPT-based empirical correlations. For CPT, measured cone tip resistance (q_c) and, where available, sleeve friction (f_s) were used within established CPT-bearing capacity frameworks to derive estimates of ultimate bearing capacity at selected depths. CPT data interpretation for design typically relies on empirically supported relationships linking q_c to soil strength and bearing parameters [13].

For SPT, the measured N-values were used in published SPT-bearing capacity correlations that relate N-values to soil strength and bearing resistance [10]. Both methods were applied under consistent assumptions of shallow footing geometry and embedment depth, ensuring that differences in estimated bearing capacity reflect the influence of test method and equipment capacity rather than variations in assumed foundation parameters.

The cohesive and cohesionless soil correlations were selected based on the interpreted soil types along each profile. The consistent use of foundation depth and geometry in both CPT and SPT frameworks enables a direct evaluation of method performance in estimating bearing capacity under the same design context.

3.4.1 CPT-Based Bearing Capacity

The ultimate bearing capacity q_u from CPT data was estimated using the [15] method.

$$q_u = k \cdot q_c \quad 1$$

Where:

q_u = ultimate bearing capacity (kN/m²)

q_c = average cone tip resistance over influence depth

k = empirical factor depending on soil type (0.3–0.5 for soft clays and silty soils)

There is the allowable bearing capacity.

$$q_a = \frac{q_u}{FS} \quad 2$$

Where:

q_a = allowable bearing capacity (kN/m²)

FS = factor of safety (commonly 3 for shallow footings).

3.4.2 SPT-Based Bearing Capacity

Ultimate bearing capacity estimates from the Standard Penetration Test (SPT) data were derived through a two-step procedure involving (i) correction and interpretation of the measured blow counts and (ii) application of classical bearing capacity theory using soil strength parameters inferred from the SPT results.

The recorded SPT blow counts N were converted to energy-corrected values N_{60} to account for differences in hammer efficiency and test configuration, following established practice [16, 8, 5]. In cases where full correction factors were unavailable, the measured N -values were treated as approximate N_{60} values, and this limitation was accounted for in the interpretation.

For sandy and silty layers, the effective friction angle ϕ was estimated from N_{60} using commonly adopted empirical correlations of the form:

$$\phi = 27^\circ + 0.3N \quad (N_{60} \leq 30) \quad 3$$

[8], whereas for clayey layers, the undrained shear strength c_u was estimated from:

$$c_u = \alpha N_{60} \quad 4$$

where α typically ranges from 4 to 7 kN/m² per blow, and a representative value of 5 kN/m²/blow was adopted in this study, in line with common practice [17, 8].

The ultimate bearing capacity q_u was then computed using the classical bearing capacity equation for shallow foundations [18, 11]:

$$q_u = C'N_c + \gamma D_f N_q + 0.5\gamma B N_\gamma \quad 5$$

where c' is the effective cohesion (or c_u for undrained clay conditions), γ is the unit weight of soil, D_f is the foundation embedment depth, B is the footing width, and N_c , N_q , and N_γ are bearing capacity factors expressed as functions of the friction angle ϕ .

For undrained clay layers ($\phi = 0$), the simplified expression was adopted:

$$q_u = 5.14c_u + \gamma D_f \quad 6$$

which is appropriate for strip or square footings under undrained loading conditions [18, 11].

Where required for comparison with CPT-based results and practical design interpretation, the allowable bearing capacity q_a was obtained from:

$$q_a = \frac{q_u}{FS} \quad 7$$

using a factor of safety $FS = 3$, consistent with common practice for shallow foundations in soft-to-medium soils.

4 Result and Discussion

4.1 Subsurface Profiles from CPT and SPT

Figure 2 presents typical cone tip resistance (q_c) profiles with depth obtained from the 10-ton and 2.5-ton CPT soundings. The profiles show a low-resistance near-surface layer, corresponding to the organic/soft clay horizon, underlain by layers of progressively increasing resistance with depth. The general trend indicates an increase in q_c with depth, reflecting the transition from very soft to stiffer and denser soil units.

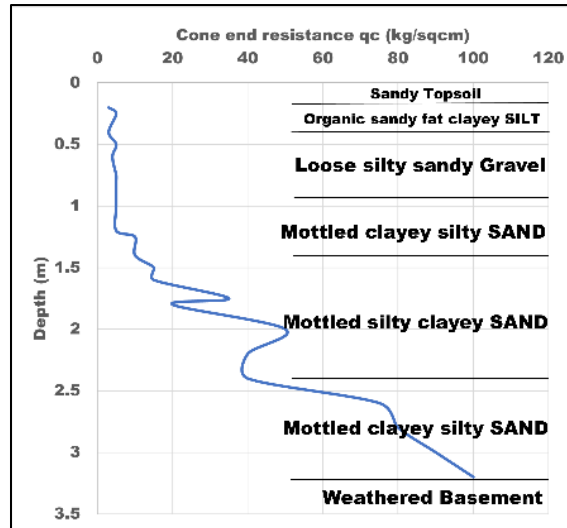


Figure 2 qc vs depth profiles from CPT results

Figure 3 shows the sleeve friction (f_s) profiles from the 10-ton CPT. Low f_s values are observed in near-surface soft soils, whereas higher values occur at greater depths, consistent with increased soil strength and density. Variations in f_s also highlight stratigraphic changes within the soil profile.

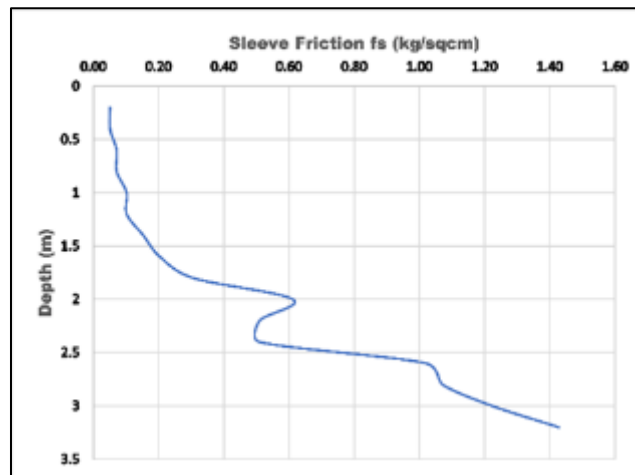


Figure 3 f_s vs depth profiles for 10-ton CPT

Figure 4 presents the Standard Penetration Test (SPT) N-value profiles as a function of depth. The N-values are generally low in the shallow layers and increase with depth, indicating very soft to soft soils near the surface and medium to stiff soils at greater depths. Although the SPT results show greater scatter than the CPT profiles, the overall stratigraphic trends are consistent with those inferred from the CPT data.

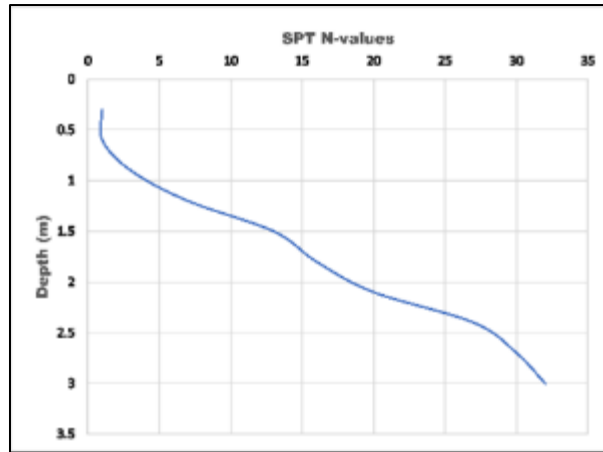


Figure 4 SPT N-value vs depth profiles

4.2 Comparison of Cone Tip Resistance from 2.5-ton and 10-ton CPT

Figure 5 compares the q_c profiles obtained from the 2.5-ton and 10-ton CPT soundings at a representative location. Both systems capture similar stratigraphic trends, with low q_c values in the shallow soft soils and increasing resistance with depth. However, the 10-ton CPT generally records higher q_c values in deeper, stiffer layers, reflecting its greater penetration capacity and improved performance in denser soils.

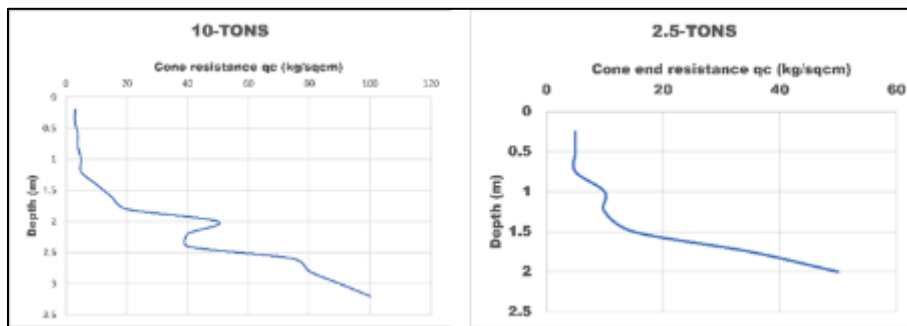


Figure 5 q_c vs depth profiles for 10-ton and 2.5-ton CPT

Table 1 summarises the mean q_c values at selected depth intervals for both CPT systems. The differences between the two datasets are relatively small in the shallow soft layers but become more pronounced with increasing depth, where the 2.5-ton CPT tends to underestimate resistance compared to the 10-ton CPT.

Table 1 Summary statistics of q_c values at selected depth intervals

Depth interval (m)	Mean q_c 2.5-tons (kN/m ²)	Mean q_c 10-tons (kN/m ²)	Difference (%)
0.0 – 0.5	5	3.3	51.5
0.5 – 1.0	7.5	6.5	15.4
1.0 – 1.5	11.7	8.8	33
1.5 – 2.0	33.3	35	4.9
2.0 – 2.5	Refusal	51.3	NA
2.5 – 3.0	Refusal	85	NA

4.3 Sleeve Friction Behaviour from the 10-ton CPT

The sleeve friction (f_s) profiles obtained from the 10-ton CPT are shown in Figure 3. The f_s values are generally low within the near-surface soft organic and clayey soils and increase with depth as the soils become stiffer and denser.

Local variations in f_s correspond to changes in soil type and stratigraphy, providing additional insight into the subsurface layering when interpreted alongside the q_c profiles.

The combined interpretation of q_c and f_s indicates a consistent stratigraphic sequence across the investigated sites, with the CPT results offering a continuous and detailed characterisation of the subsurface conditions.

4.4 Bearing Capacity Estimates from CPT and SPT

Table 2 presents the allowable bearing capacity estimates derived from the 2.5-ton CPT, 10-ton CPT, and SPT data, respectively, using the methods described in Section 3. The results indicate a general increase in estimated bearing capacity with depth, consistent with the observed increase in soil resistance.

Table 2 also provides a direct comparison of bearing capacity values obtained from the three methods at corresponding depths and locations. In the shallow soft layers, the differences between the methods are relatively small. In contrast, in the deeper and stiffer layers, the 10-ton CPT and SPT generally yield higher bearing capacity estimates than the 2.5-ton CPT.

Table 2 Comparison of bearing capacity estimates from CPT and SPT

Depth interval (m)	Mean q_a 2.5-tons (kN/m ²)	Mean q_a 10-tons (kN/m ²)	Mean q_a SPT (kN/m ²)
0.0 – 0.5	49.03	32.7	6.02
0.5 – 1.0	73.6	44.13	123.98
1.0 – 1.5	122.6	8.8	33
1.5 – 2.0	416.8	343.2	634.8
2.0 – 2.5	Refusal	506.7	1098
2.5 – 3.0	Refusal	833.6	1672.3

Figure 6 illustrates the variation of bearing capacity with depth for the three methods at a representative location. While all methods show similar overall trends, systematic differences are evident, highlighting the influence of test type and equipment capacity on the derived design parameters.

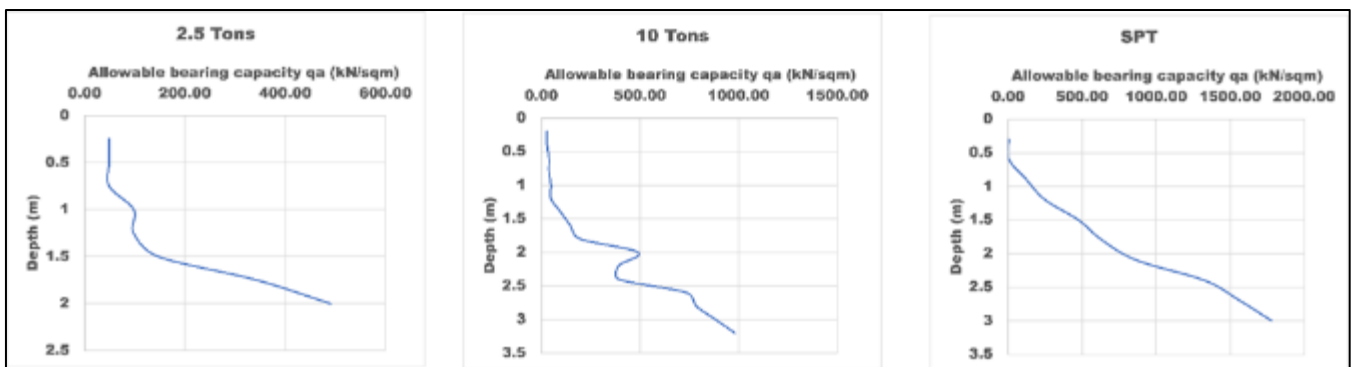


Figure 6 Bearing capacity vs depth from 2.5-ton CPT, 10-ton CPT, and SPT

4.5 Comparison of Bearing Capacity Estimates with Depth

A comparison of bearing capacity estimates derived from the 2.5-ton CPT, 10-ton CPT, and SPT is summarised in Table 2. All methods show a systematic increase in bearing capacity with depth, consistent with the progressive increase in soil stiffness and strength within the subsurface profile.

In the shallow layer (0.0–0.5 m), the CPT-based estimates exceed the SPT value, reflecting the very low resistance of near-surface soils and the SPT's greater sensitivity to very soft strata. Between 0.5 m and 2.0 m depth, the SPT-derived bearing capacities become markedly higher than those obtained from both CPT systems, indicating a stronger response of the SPT to increasing soil strength in these layers.

Below 2.0 m depth, the 2.5-ton CPT reaches refusal, demonstrating the limitation of this equipment in the stiffer soil layers. In contrast, the 10-ton CPT continues to provide measurable resistance, with estimated bearing capacities increasing from approximately 507 kN/m² at 2.0–2.5 m to about 834 kN/m² at 2.5–3.0 m. Over the same depth intervals, the SPT yields substantially higher values, exceeding 1000 kN/m² and reaching approximately 1672 kN/m² at 2.5–3.0 m.

These results indicate that although the three methods capture similar depth-dependent trends, the absolute magnitude of the estimated bearing capacity is strongly influenced by the test method and equipment capacity. The 2.5-ton CPT provides conservative estimates and becomes unsuitable in the deeper, stiffer layers, whereas the 10-ton CPT and SPT remain effective. The consistently higher values obtained from the SPT highlight the importance of careful cross-comparison and calibration when using different in-situ tests for foundation design in stiff or dense soils.

5 Conclusions and Practical Implications

5.1 Conclusions

This study has presented a comparative evaluation of bearing capacity estimates derived from 2.5-ton CPT, 10-ton CPT and SPT data in swampy tropical soils of Akure, southwestern Nigeria. The investigation was motivated by the widespread use of these in situ tests in tropical lowland environments and the uncertainty associated with applying standard correlations without accounting for equipment capacity and local ground conditions.

Based on analysis of the in-situ test profiles, the subsurface conditions are characterised by a near-surface layer of soft to very soft organic clay, underlain by progressively stiffer clayey and silty sands. Both CPT and SPT results consistently capture this stratigraphic trend, with low resistance in the shallow layers and increasing resistance with depth. The 10-ton CPT provided continuous and reliable measurements across the full investigated depth range, including both cone resistance and sleeve friction, whereas the 2.5-ton CPT reached refusal in the deeper, stiffer layers, limiting its applicability at depth.

Comparison of cone resistance measurements from the two CPT systems shows that differences are relatively small in the shallow soft layers but become more pronounced with depth, where the 2.5-ton CPT tends to underestimate soil resistance relative to the 10-ton CPT. This demonstrates the influence of equipment capacity on measured resistance and highlights the risk of relying on low-capacity CPT systems in moderately stiff to stiff tropical soils.

Bearing capacity estimates derived from CPT and SPT data show a consistent increase with depth, reflecting the improving soil strength and stiffness. However, systematic differences in magnitude are evident between methods. The 2.5-ton CPT generally provides more conservative estimates and becomes unsuitable at depth due to refusal, while the 10-ton CPT continues to yield usable results. The SPT, in contrast, produces higher bearing capacity values in the intermediate to deeper layers, indicating a stronger response to increasing soil strength in these strata. These findings confirm that, although the methods capture similar trends, the absolute design values are strongly dependent on the test method and equipment capacity.

Overall, the results demonstrate that the direct application of standard CPT- and SPT-based correlations, without accounting for equipment limitations and local soil conditions, can lead to significant discrepancies in estimated bearing capacity in swampy tropical environments. Site-specific comparison and calibration of in-situ test data are therefore essential for reliable foundation design in such settings.

5.2 Practical relevance and applications

The findings of this study have direct implications for geotechnical practice in tropical lowland and swampy terrains, particularly in regions underlain by weathered basement complex and transported soft soils, such as southwestern Nigeria. First, the results show that low-capacity CPT systems (e.g. 2.5-ton rigs), although useful in very soft soils, may be inadequate for characterising deeper or stiffer layers and may lead to overly conservative or incomplete design assessments due to early refusal. For routine site investigations where deeper foundation levels are anticipated, higher-capacity CPT systems (e.g. 10-ton rigs) should be preferred to ensure continuous and reliable profiling.

Second, the consistently higher bearing capacity values obtained from SPT tests in the deeper layers highlight the need for caution when relying solely on SPT-based correlations for design in tropical soils. Without cross-checking against CPT data or local experience, there is a risk of overestimating bearing capacity, which could compromise safety.

Conversely, exclusive reliance on low-capacity CPT data may result in overly conservative designs and uneconomical foundation solutions.

In practical terms, this study supports a combined and comparative use of CPT and SPT in swampy tropical environments, with particular emphasis on (i) selecting appropriate CPT equipment capacity for the expected ground conditions, (ii) interpreting results within the local geological and hydrogeological context, and (iii) cross-validating bearing capacity estimates from different in-situ tests before final design decisions are made. The approach and findings presented here can be directly applied to similar lowland and swampy sites in Nigeria and other tropical regions, contributing to safer, more reliable and more economical foundation design.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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