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Validity of SPT–CPT Correlation for Bearing Capacity Prediction of Reclaimed Soils in Lagos Island, Lagos State, Nigeria

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Abstract

Background: Engineers often apply published, generic SPT–CPT correlation ratios to estimate one test from the other when only one is available. These ratios were developed for natural soils, and their validity for reclaimed soils in Lagos Island, Nigeria, has not been tested. Methods: Secondary SPT, CPT and borehole data from six reclaimed sites in Ikoyi, Victoria Island, Lekki and Sangotedo were analysed. Allowable bearing capacity was computed from SPT data using Meyerhof's general bearing capacity equation (factor of safety of 3) and from CPT data using Meyerhof's (1956) direct method. The site-derived ratio qc/N was compared with published values from Brazil (Danziger et al., 0.39 MPa) and the United Arab Emirates (Akça, 0.30–0.45 MPa), including a one-sample t-test. Results: SPT-based allowable bearing capacity ranged from 237.5 to 404.5 kPa and CPT-based capacity from 245.2 to 653.8 kPa. The site-derived qc/N had a mean of 0.559 MPa (range 0.245–0.823 MPa), a coefficient of variation of 40.3% and a 95% confidence interval of 0.323–0.795 MPa. Only one of the six sites (Site A, 0.441 MPa) fell within the published range, although the mean did not differ significantly from the Danziger value ($p = 0.13$). Conclusion: Published generic SPT–CPT correlation ratios are not reliable for reclaimed soils in Lagos Island, because only one of the six sites fell within the published range. Site-specific data should be used or, where unavailable, the site-derived mean or the wider 95% confidence interval established here should be adopted as a fallback.

Keywords: Bearing capacity; Cone Penetration Test; reclaimed soils; SPT–CPT correlation; Standard Penetration Test

1 Introduction

1.1 Background

Land reclamation responds to land scarcity in coastal cities such as Lagos, where population growth has raised the demand for commercial, residential and infrastructure land while dry land has become practically exhausted. Lagos had an estimated population of about 17.16 million in 2025, growing at 3.75% per year [1]. A large share of the urbanised area lies less than 5 m above sea level, and limited room for outward expansion makes reclamation both necessary and geotechnically significant. Lekki, Victoria Island, Ikoyi and Banana Island were originally swampy or waterlogged and are now extensively developed. Notable reclamation projects include Eko Atlantic City, where 652 ha of a planned 1,000 ha (65%) had been reclaimed by May 2025 [2, 3, 4], the Lekki Foreshore Scheme, Orange Island, and the Alaguntan/Okunkobo/Olomometa area of Ojo Local Government Area [5, 6].

Reclamation involves site investigation, assessment of the fill material (dredged sand or sand from borrow pits) and compaction [7]. The placement method (dry filling, hydraulic filling, direct dumping

or sand spreading) depends on water depth, soil strength and available fill, and it directly affects the density and quality of the resulting ground. Reclaimed soils are characteristically of low density, non-uniform, and may contain organic matter, with high moisture content and compressibility, so they are more prone to settlement and lower bearing capacity than natural, undisturbed soils. Organic matter such as peat holds water and decomposes over time, leaving voids that weaken the soil and increase its compressibility [8]. Comparable problems are documented elsewhere. Hong Kong has about 7,000 ha of reclaimed land [9], where hydraulically placed fill over soft marine clay is prone to bearing failure and settlement because of low shear strength and high compressibility [10]; at Changi East, Singapore, vertical drains and surcharge were used to consolidate the soft marine clay beneath dredged sand fill [11].

Lagos Island lies within the Benin Formation and recent littoral and lagoon alluvial deposits [12]. The pre-reclamation ground consists of loose sand to about 4 m, soft and peaty clay to about 6 m, and organic clay with carbonised vegetable matter within this sequence, with medium to very dense sand containing traces of gravel commonly found at about 30 m [12]. Peat can be 5 to 20 times more compressible than soft clay [13], so shallow foundations on or near it are risky and deep foundations are usually preferred.

1.2 In situ testing and bearing capacity

The Standard Penetration Test (SPT) drives a split-spoon sampler with a 63.5 kg hammer dropped from 750 mm; the number of blows for the last 300 mm of a 450 mm drive is the N-value [14]. The test is operator- and equipment-dependent, with coefficients of variation of 15–30% reported between rigs, drillers and borehole conditions, and it performs poorly in soft clays and in dense gravels [15]. The Cone Penetration Test (CPT) pushes an electronic cone at 2 cm/s while continuously recording cone resistance (q_c) and sleeve friction (f_s) [16]. It provides continuous and repeatable data, but its equipment is costly and requires expert operators, so the SPT remains in wide use. Bearing capacity can be computed from SPT data through the friction angle using Terzaghi's [17] or Meyerhof's [18] equations, or directly from q_c [19].

1.3 SPT–CPT correlation studies

Robertson et al. [20] established that the ratio q_c/N increases with mean grain size (D_{50}); this relationship is the usual baseline for later studies. Danziger et al. [21] obtained a representative q_c/N_{60} of 0.39 MPa for Brazilian soils using a geostatistical (semivariogram) approach. Kara and Gündüz [22] found low q_c/N correlation coefficients (0.29–0.51) for the heterogeneous soils of Adapazarı, Turkey, giving ratios below literature values. Akça [23] recommended q_c/N of 0.30–0.45 MPa for the United Arab Emirates, higher than widely reported values because of cementation, densification and shelly structure. These studies show that q_c/N varies from region to region with soil structure and composition, so a ratio established in one region cannot be assumed valid in another.

1.4 Research problem, gap and objectives

When only one of SPT and CPT is available, because of client budget, time pressure or equipment availability, engineers commonly estimate the other from a published generic ratio [20] and use it to compute bearing capacity. Reclaimed soils in Lagos Island consist of loose dredged sand, medium dense sand, sandy clay, organic clay and peat pockets that are unevenly compacted and overlie soft marine deposits, whereas the published ratios were derived from natural soils elsewhere. An overestimate of strength risks under-design and foundation distress; an underestimate causes over-

design and unnecessary cost. The reviewed studies were all carried out on natural soils in Turkey, Brazil and the United Arab Emirates, and no test of the ratio on Lagos Island reclaimed soils was found.

This study therefore assesses the validity of published generic SPT–CPT correlation ratios for bearing capacity prediction of reclaimed soils in Lagos Island. Its objectives are (i) to determine the bearing capacity of reclaimed soil at six sites using SPT-based and CPT-based methods; (ii) to determine the site-derived ratio q_c/N and compare it with published ratios; and (iii) to ascertain the validity and reliability of the published ratios for predicting the bearing capacity of these soils. If the published ratios applied to these soils, most site-derived ratios would be expected to fall within the published range and the SPT-based and CPT-based capacities would be expected to agree; the study tests this expectation.

2 Methods

The study followed the workflow shown in Figure 1: data collection, calculation of bearing capacity by SPT-based and CPT-based methods, comparison of the site-derived q_c/N with published ratios, comparison of the two bearing capacity estimates, and assessment of the validity of the published ratios.

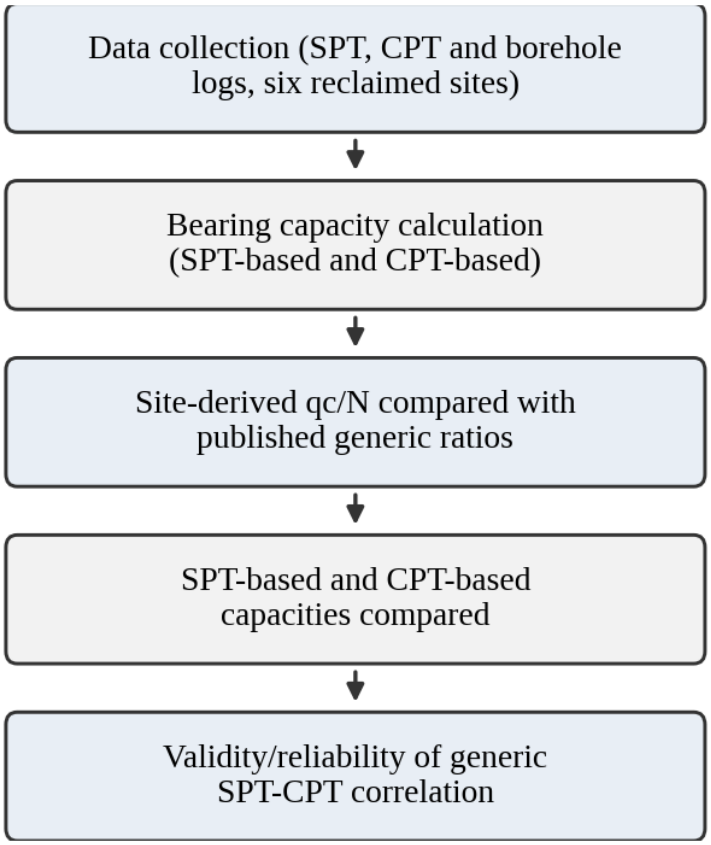


Figure 1. Workflow of the study.

2.1 Study area and sites

For this study, Lagos Island refers to the broader island landmass comprising Lagos Island proper, Ikoyi, Victoria Island, Lekki and Sangotedo, which lie on the same island system but span the Lagos Island and Eti-Osa Local Government Areas and are bounded by lagoons, the Atlantic Ocean and rivers [5]. Reclamation of Ikoyi (258 acres) began in 1918, with physical development from 1925 [24]. The eastern swamps of Victoria Island were sand-filled from about 1948 [25], and the shallow swamplands of Lekki were reclaimed in the 1990s [26]. Six sites (A–F) were studied (Table 1). Sites A, B and F lie on older reclaimed land (1920s–1940s) and Site C on land reclaimed in the 1990s; the reclamation dates of Sites D and E were not documented.

Table 1. Study sites.

Site	Location	Development	Reclamation period
A	Ikoyi	Proposed residential	Older (1920s–1940s)
B	Victoria Island	Proposed residential	Older (1920s–1940s)
C	Lekki	Residential	1990s
D	Sangotedo	Proposed residential	Not documented
E	Sangotedo	Residential	Not documented
F	Ikoyi	Proposed commercial (7-storey)	Older (1920s–1940s)

2.2 Data sources

A quantitative, comparative design was adopted using secondary data from existing geotechnical investigation reports prepared by licensed consultancy firms, including the Lagos State Materials Testing Laboratory; no new field investigation was carried out. The reports were obtained from the consultancy firms, the laboratory and clients. For each site, SPT N-values and CPT q_c and f_s values at different depths, together with borehole logs, were extracted and tabulated. N-values and q_c values were cross-checked against the depths recorded in the borehole logs, and missing or incomplete data were excluded for the specific point. Site E had the largest dataset (20 boreholes and 20 CPTs). Where CPT data were presented only as graphs (Site D), values were read from the plots, and for Site C q_c was back-calculated from the reported allowable bearing capacity. Values reported in different units were converted using 1 kg/cm^2 = 98.07 kPa = 0.0981 MPa.

2.3 SPT-based bearing capacity

The ultimate bearing capacity was computed with Meyerhof's general bearing capacity equation [18, 27]:

$$q_u = cN_c s_c d_c i_c + qN_q s_q d_q i_q + 0.5\gamma B N_\gamma s_\gamma d_\gamma i_\gamma \quad (1)$$

where c is cohesion, $q = \gamma D_f$ is the surcharge pressure, γ is the unit weight, B is the footing width, N_c, N_q and N_γ are bearing capacity factors that depend on the friction angle φ, and s, d and i are shape, depth and inclination factors. The soils were treated as cohesionless (c = 0) with shape, depth and inclination factors taken as 1, γ = 18 kN/m^3, and a uniform footing of B = 1.5 m at D_f = 1.5 m was assumed at all sites for comparability. Because φ cannot be measured by SPT, it was estimated from the N-value with the correlation of Peck et al. [28]:

$$\varphi = 27.1 + 0.3N - 0.00054N^2 \quad (2)$$

and Meyerhof's factors for the resulting φ were used. The allowable bearing capacity followed from

$$q_a = \frac{q_u}{\mathrm{FS}}, \ \mathrm{FS} = 3 \tag{3}$$

As a worked example, Site A (N = 10) gives φ = 27.1 + 3.0 − 0.054 = 30.05°, and Meyerhof's factors for this angle are N_c = 30.25, N_q = 18.50 and N_γ = 15.79. With q = 18 × 1.5 = 27 kPa, q_u = 27 × 18.50 + 0.5 × 18 × 1.5 × 15.79 = 712.6 kPa and q_a = 712.6/3 = 237.5 kPa (Table 3).

Representative N-values were taken from the competent bearing stratum at or near the founding depth recommended in each site's report, so that the analysis reflects realistic foundation conditions. N-values were used as reported in the consultants' investigation reports; the reports do not state whether energy or overburden corrections had been applied. For the depth analysis (Sites A, C and D), D_f was taken as the test depth, and the sensitivity of q_a to footing width was examined for B = 1–3 m at Sites A and F.

2.4 CPT-based bearing capacity

The allowable bearing pressure was computed directly from cone resistance with the method of Meyerhof [19] for a settlement of 25 mm and footing width B > 1 m:

$$q_a = \left(\frac{q_c}{50}\right)\left(1 + \frac{1}{B}\right)^2 \tag{4}$$

with q_a and q_c in kg/cm^2 and B in metres (B = 1.5 m), converted to kPa. Representative q_c values were taken from the competent stratum at or near the recommended founding depth. Because each site was investigated independently by a different consultant, the depths at which CPT data are available differ from site to site.

For Site A (q_c = 45 kg/cm^2, B = 1.5 m), q_a = (45/50)(1 + 1/1.5)^2 = 2.5 kg/cm^2 = 245.2 kPa (Table 4).

2.5 Site-derived correlation ratio and statistical analysis

For each site the ratio q_c/N (MPa) was calculated from the representative q_c (converted to MPa) and N. The site-derived ratio is the mean of the six site values. Variability was expressed by the sample standard deviation (s, n − 1 degrees of freedom), the coefficient of variation (CoV = s/mean × 100), the standard error of the mean (SEM = s/√n) and the 95% confidence interval (mean ± t × SEM, with t = 2.571 for 5 degrees of freedom [29]). The deviation of the site-derived mean from the published ratios was expressed as a percentage, and a two-sided one-sample t-test (α = 0.05, 5 degrees of freedom) compared the site-derived mean with the Danziger et al. value (0.39 MPa) and with the midpoint of the Akça range (0.375 MPa).

3 Results

3.1 Subsoil conditions

Subsoil conditions varied considerably across the sites (Table 2). Site A (Ikoyi) has the thickest weak layer, 23 m of organic clay, and Site C (Lekki) the thinnest, a 3 m clay layer. Site D contains 5.5 m of peat and a separate clay band, and Site E a 1.5–4.5 m clay band sandwiched within the profile. Sites B and F consist entirely of sand. Sites A and F, both in Ikoyi, show opposite conditions: 23 m of organic clay at Site A and sand only at Site F.

Table 2. Subsoil conditions and recommended foundations at the six sites.

Site	Weak layer	Thickness (depth range)	Foundation recommended in original report
A	Organic clay	23 m (6.0–29.25 m)	Bored pile at 38.0 m
B	None (all sand)	–	Raft at 1.0–1.5 m or pile at 7.0 m
C	Organic clay	3 m (6.0–9.0 m)	Bored pile at 14–15 m
D	Peat and clay	5.5 m peat + 2.55 m clay	Piles at 12 and 22 m
E	Sandwiched clay band	1.5–4.5 m (about 12–17 m depth)	Piles at 9, 19 and 21 m
F	None (all sand)	–	Bored pile at 14 m

3.2 SPT-based bearing capacity

Table 3 gives the SPT-based results for the representative depths. The allowable bearing capacity ranged from 237.5 kPa (Site A) to 404.5 kPa (Site F). Sites C and D gave 347.0 and 360.5 kPa, whereas Site E gave 256.1 kPa and Site B 276.2 kPa. The two Ikoyi sites (A and F) gave the lowest and highest values of the six.

Table 3. SPT-based bearing capacity at the representative depths (B = Df = 1.5 m, FS = 3).

Site	N	ϕ (°)	N_c	N_q	N_γ	q_u (kPa)	q_a (kPa)
A	10	30.0	30.25	18.50	15.79	712.6	237.5
B	14	31.2	33.19	21.10	19.19	828.7	276.2
C	20	32.9	38.25	25.73	25.65	1041.0	347.0
D	21	33.2	39.18	26.60	26.91	1081.6	360.5
E	12	30.6	31.68	19.75	17.41	768.4	256.1
F	24	34.0	42.12	29.40	31.09	1213.5	404.5

3.3 CPT-based bearing capacity and comparison with SPT

The CPT-based allowable bearing capacity ranged from 245.2 kPa (Site A) to 653.8 kPa (Site F) (Table 4), so Site F ranks highest and Site A lowest under both methods. The two methods agreed closely only at Site A (+3.2%). At the other sites the CPT-based value was higher by 61.6–131.8%, except at Site C, where the SPT-based value was higher (−21.5%) (Figure 2). At Site A the N-value (1.5 m) and q_c (13.0 m) came from different depths yet the capacities agreed, whereas at Site B both came from the same layer (2.25–8.25 m) and differed by 131.8%.

Table 4. CPT-based allowable bearing capacity and comparison with the SPT-based values.

Site	CPT data source	q_c (kg/cm^2)	q_a CPT (kPa)	q_a SPT (kPa)	Difference (kPa)	Difference (%)
A	CPT2 at 13.0 m	45	245.2	237.5	7.7	+3.2
B	Area A, 2.25–8.25 m layer (mid-point)	117.5	640.2	276.2	364.0	+131.8
C	CPT2 at 1.75 m (back-calculated)	50	272.4	347.0	−74.6	−21.5
D	P1 at 10.0 m (read from graph)	115	626.5	360.5	266.0	+73.8

Site	CPT data source	q_c (kg/cm^2)	q_a CPT (kPa)	q_a SPT (kPa)	Difference (kPa)	Difference (%)
E	BH1, 2.25–12.75 m layer (mid-point)	100	544.8	256.1	288.7	+112.7
F	Layer II average (report-stated)	120	653.8	404.5	249.3	+61.6

Difference = (CPT-based − SPT-based) / SPT-based.

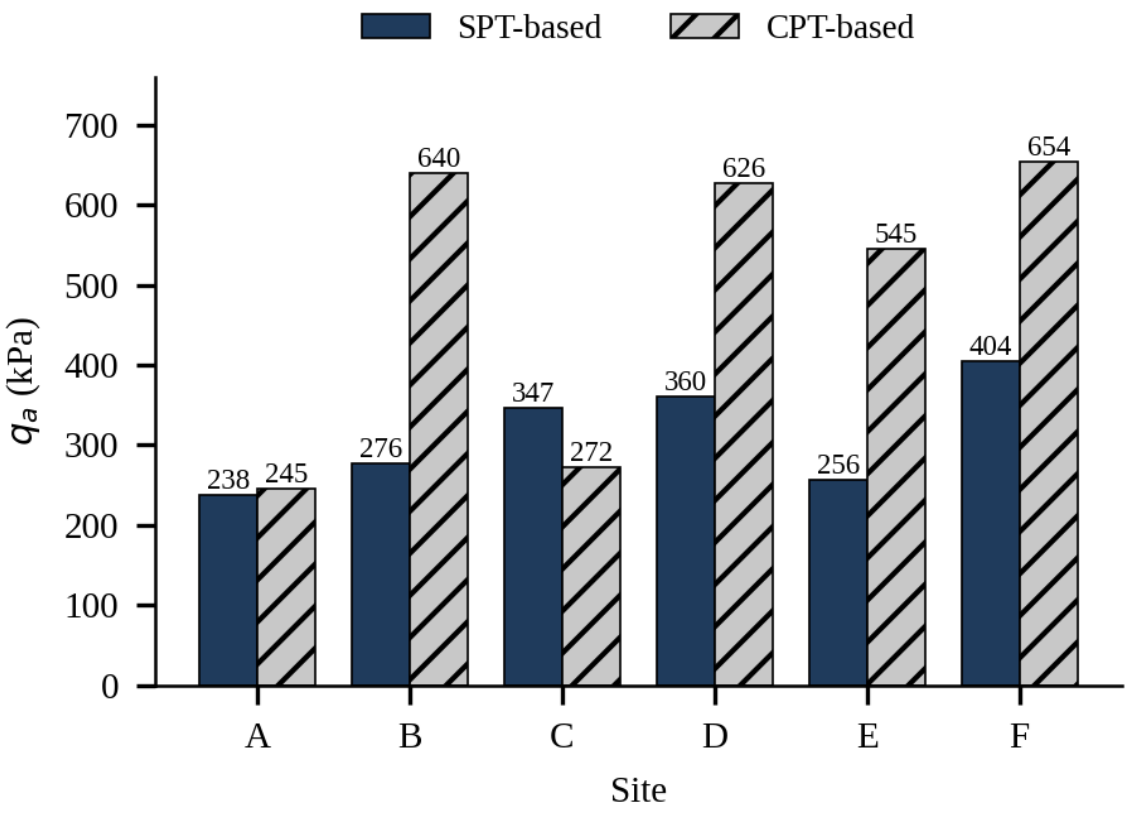


Figure 2. SPT-based and CPT-based allowable bearing capacity at the six sites.

3.4 Variation with depth and footing width

Table 5 and Figure 3 show the SPT-based capacity with D_f taken as the test depth. Capacity increased with depth at Sites A and C. At Site D it fell sharply at 18 m (N = 5), where the borehole log shows a clay layer, from 2983.0 kPa at 15 m to 1751.6 kPa. The CPT profiles read from the penetrometer graphs for Sites A and D are summarised in Table 6 and show the same contrast between weak and competent strata.

Table 5. SPT-based allowable bearing capacity with depth (Df = test depth, B = 1.5 m).

Site	Depth (m)	N	q_a (kPa)
A	1.5	10	237.5
A	3.0	11	418.7
A	37.5	10	4233.0

Site	Depth (m)	N	q_a (kPa)
A	39.0	13	4859.3
A	40.0	14	5150.1
C	6.0	10	737.0
C	9.0	6	934.6
C	13.5	20	2199.8
C	18.0	27	3672.1
C	24.0	32	5744.2
D	1.5	3	182.7
D	9.0	6	934.6
D	15.0	26	2983.0
D	18.0	5	1751.6
D	25.5	28	5312.6

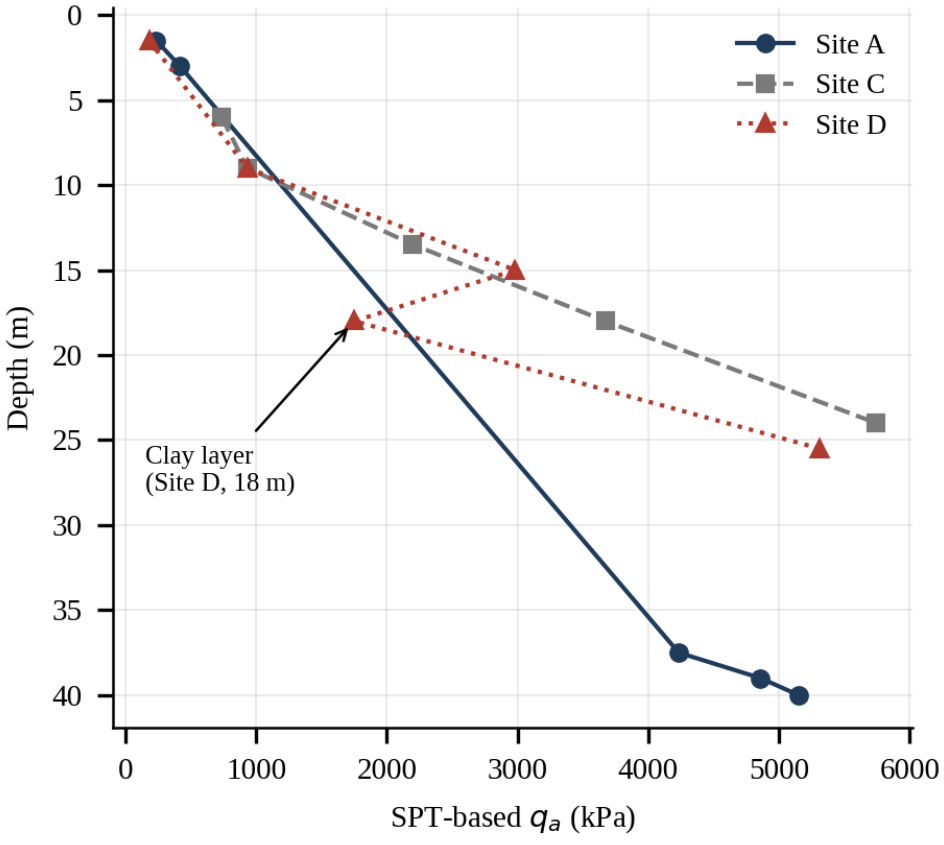


Figure 3. Variation of SPT-based allowable bearing capacity with depth for Sites A, C and D (lines join the tested depths).

Table 6. CPT-based bearing capacity profile with depth at Sites A and D (read from the penetrometer graphs).

Site	Depth (m)	q_c (kg/cm^2)	q_a (kPa)	Stratum
A	0.0–3.25	15–160	82–872	Medium dense sand

Site	Depth (m)	q_c (kg/cm^2)	q_a (kPa)	Stratum
A	4.5–13.0	8–45	44–245	Sandy clay / organic clay
D	0.5–6.5	8–10	44–55	Peat
D	7.5–10.2	30–115	163–627	Sand

Table 7 shows that q_a increases with footing width at both Site A (lowest capacity) and Site F (highest), because the N_γ term scales with B. Site F exceeds Site A at every width, so the assumed B = 1.5 m does not change the ranking of the sites.

Table 7. Sensitivity of SPT-based allowable bearing capacity to footing width.

B (m)	Site A, q_a (kPa)	Site F, q_a (kPa)
1.0	213.8	357.9
1.5	237.5	404.5
2.0	261.2	451.1
2.5	284.9	497.7
3.0	308.6	544.4

3.5 Site-derived SPT–CPT correlation ratio

The site-derived q_c/N values are given in Table 8. They range from 0.245 MPa (Site C) to 0.823 MPa (Site B), a more than three-fold difference between two sites on the same island system, with a mean of 0.559 MPa. The standard deviation is 0.225 MPa and the coefficient of variation is 40.3%, indicating large variability. Table 9 gives the additional statistics; the 95% confidence interval of the mean is 0.323–0.795 MPa, and the one-sample t-tests found no significant difference between the mean and either published value (p = 0.126 and 0.102).

Table 8. Site-derived SPT–CPT correlation ratio (qc/N).

Site	N	q_c (kg/cm^2)	q_c (MPa)	q_c/N (MPa)
A	10	45	4.413	0.441
B	14	117.5	11.523	0.823
C	20	50	4.903	0.245
D	21	115	11.278	0.537
E	12	100	9.807	0.817
F	24	120	11.768	0.490

Table 9. Statistical measures of the site-derived qc/N ratio (n = 6).

Statistic	Value
Minimum	0.245 MPa (Site C)
Maximum	0.823 MPa (Site B)
Range	0.578 MPa
Median	0.514 MPa

Statistic	Value
Mean	0.559 MPa
Standard deviation	0.225 MPa
Standard error of the mean	0.092 MPa
Coefficient of variation	40.3%
95% confidence interval	0.323–0.795 MPa
One-sample t-test vs. 0.39 MPa	t = 1.83, df = 5, p = 0.126
One-sample t-test vs. 0.375 MPa	t = 2.00, df = 5, p = 0.102

The site-derived mean is 43.3% higher than the Danziger et al. value [21] and 49.1% higher than the midpoint of the Akça range [23] (Table 10, Figure 4). Only Site A (0.441 MPa) falls within the published UAE range. Site C (0.245 MPa) lies below it, Sites B (0.823 MPa) and E (0.817 MPa) lie far above it, and Sites D (0.537 MPa) and F (0.490 MPa) lie moderately above it.

Table 10. Comparison of the site-derived ratio with published generic ratios.

Source	Location	q_c/N (MPa)	Site-derived mean (0.559 MPa) relative to published value
Danziger et al. [21]	Brazil	0.39	+43.3% higher
Akça [23]	United Arab Emirates	0.30–0.45	+49.1% higher (vs. midpoint, 0.375)
This study (mean)	Lagos Island (reclaimed)	0.559	–

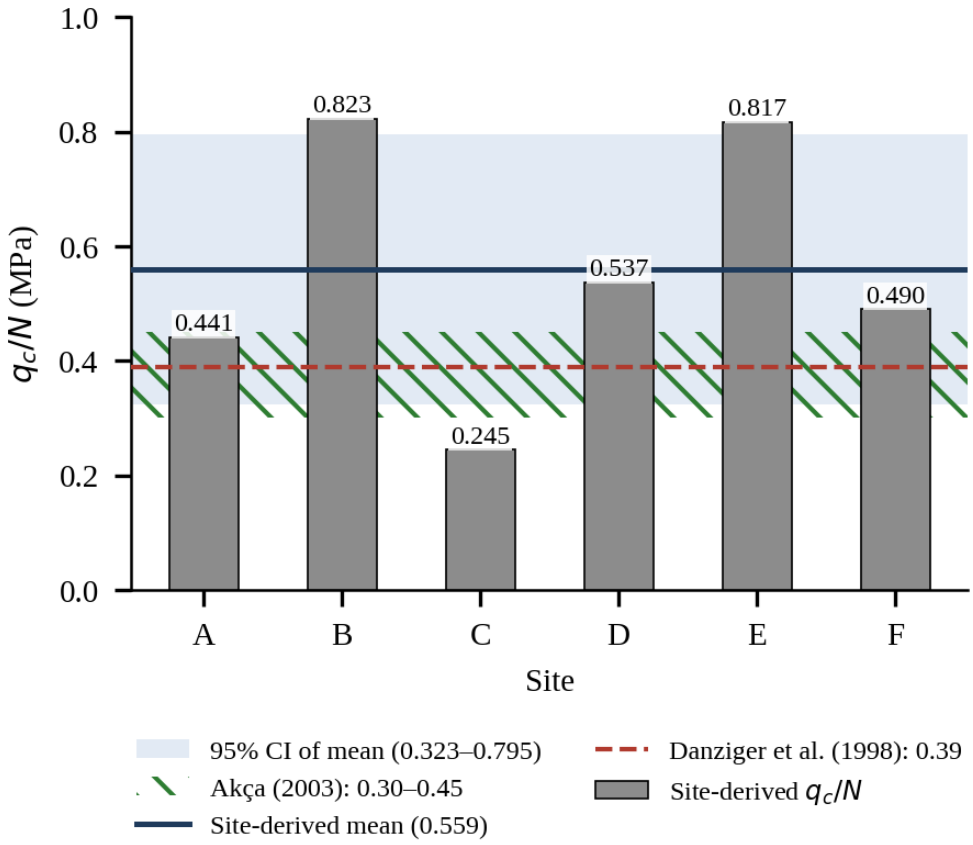


Figure 4. Site-derived qc/N at the six sites compared with the site-derived mean and its 95% confidence interval, and with published ratios.

4 Discussion

4.1 SPT-based versus CPT-based bearing capacity

The two methods rank the sites consistently at the extremes (Site F highest, Site A lowest) but disagree strongly in magnitude at most sites, with differences from −21.5% to +131.8% (Table 4). Because depth matching does not explain the pattern, the scatter is attributed mainly to the operator and equipment dependence of the SPT, which causes local variability and testing inconsistency even within the same sand layer, whereas the CPT gives more continuous and repeatable data [15]. The two calculations are also not strictly equivalent: the SPT-based value is a strength-based capacity divided by a factor of safety, whereas the CPT-based value is the allowable pressure for 25 mm settlement, so part of the difference may arise from the methods themselves. The SPT-based capacity also varies widely over short distances: the two Ikoyi sites gave the lowest (Site A, 237.5 kPa) and highest (Site F, 404.5 kPa) values, which reflects differences in the density of the sand layer rather than location or reclamation age.

4.2 Depth profiles and foundation recommendations

The depth profiles show that clay and peat layers sharply reduce bearing capacity (Figure 3, Table 6), so representative values must be taken from the competent stratum, as was done here. The presence of clay or peat does not follow reclamation age: Sites A and F, both in Ikoyi, show opposite conditions, so soil variability is site-specific rather than area-wide.

The calculated capacities at the competent strata were consistent with the foundation types recommended in the original reports (Tables 2 and 11): piles founded below the weak layers at Sites A, C, D and E, and a shallow raft at the sand-only Site B. At Site F, piles were recommended because of the heavy load of the proposed 7-storey building rather than weak soil; the calculations show Site F to be the strongest of the six sites. Bearing capacity alone therefore does not determine foundation type, since the anticipated structural load is also decisive.

Table 11. Comparison of the calculated results with the foundation recommendations in the original consultants' reports.

Site	Consultant's recommendation	Reason given	Finding of this study	Consistent?
A	Bored pile at 38.0 m	Weak organic clay (23 m); high water table	q_a = 237.5 (SPT) and 245.2 kPa (CPT)	Yes
B	Shallow raft at 1.0–1.5 m	No weak layer; competent sand near surface	q_a = 276.2–640.2 kPa; strong shallow stratum	Yes
C	Bored pile at 14–15 m	Clay layer (3 m) over loose sand	q_a = 347.0 (SPT) and 272.4 kPa (CPT)	Yes
D	Piles at 12 and 22 m	Thick peat (5.5 m) and deep clay band	q_a fell sharply at 18 m (clay) and recovered in sand at the pile depths	Yes
E	Piles at 9, 19 and 21 m	Sandwiched clay band (about 12–17 m)	q_a = 256.1–544.8 kPa at the competent stratum below the clay band	Yes
F	Bored pile at 14 m	Heavy 7-storey commercial load (not weak soil)	Highest q_a of all sites (404.5–653.8 kPa); piling is load-driven	Yes

4.3 Validity of the published correlation ratios

Three findings indicate that the published generic ratios are not reliable for reclaimed soils in Lagos Island. First, the ratio varies greatly between sites (CoV = 40.3%, range 0.245–0.823 MPa), even between neighbouring sites with very different subsoil, so no single ratio can represent the area. Second, only one of the six sites (Site A) falls within the published range, and the site-derived mean is 43–49% higher than the published values. Third, the SPT and CPT results disagree substantially at most sites. Applying the published ratios directly would therefore give inaccurate estimates of bearing capacity and lead to either over-design or under-design.

The one-sample t-tests did not reject equality of the mean with either published value ($p = 0.13$ and 0.10). With only six sites and a coefficient of variation of 40.3% the test has little power, so the conclusion that the ratios are unreliable rests on the site-to-site scatter and on the fact that only one site falls within the published range, not on a significant difference of means. The published values are not statistically impossible: the Danziger et al. value (0.39 MPa) and part of the Akça range (0.30–0.45 MPa) lie within the 95% confidence interval (0.323–0.795 MPa), but only near its lower boundary. They therefore represent an atypical, low-end case for Lagos Island rather than a representative one, particularly as the mean (0.559 MPa) is well above them. Table 12 compares the results with previous studies. The high site-to-site variability is consistent with the international pattern: Kara and Gündüz [22] likewise found low and inconsistent correlation coefficients in heterogeneous soils, which suggests that reclaimed or heterogeneous soils generally resist characterisation by a single ratio.

Table 12. Comparison of the site-derived ratio with previous SPT–CPT correlation studies.

Study	Soil and location	Reported result	Comparison with this study
Robertson et al. [20]	Natural soils	q_c/N increases with D_{50}	Baseline relationship; grain size not available for the sites here
Danziger et al. [21]	Brazilian soils	0.39 MPa (q_c/N_{60})	Site-derived mean is 43.3% higher
Kara and Gündüz [22]	Heterogeneous soils, Adapazarı, Turkey	Correlation coefficients 0.29–0.51	Consistent: heterogeneous ground gives inconsistent correlations
Akça [23]	United Arab Emirates	0.30–0.45 MPa	Site-derived mean is 49.1% higher than the midpoint; only Site A is within the range
This study	Reclaimed soils, Lagos Island	Mean 0.559 MPa (0.245–0.823)	–

4.4 Practical implications

Where only SPT data are available and no site-specific CPT exists, the ratios from this study can give an indicative estimate of q_c from N. Table 13 illustrates this for typical N-values using the lower bound, the mean and the upper bound of the 95% confidence interval. The wide spread between the bounds (about 2.5 times) shows how uncertain such an estimate is. These values are suitable for planning, feasibility and preliminary design only, and the lower bound should be preferred for a conservative estimate. They are not a substitute for site-specific testing before final design.

Table 13. Illustrative estimates of qc (MPa) from N using the site-derived ratios.

N	Lower bound (0.323 MPa)	Mean (0.559 MPa)	Upper bound (0.795 MPa)
10	3.23	5.59	7.95
20	6.46	11.18	15.90
30	9.69	16.77	23.85

4.5 Limitations

The study relies on the accuracy of existing investigation reports prepared by others, and six sites cannot represent all reclaimed areas of Lagos or other coastal regions. The results reflect conditions at the test points only. SPT and CPT data were not always available at the same depths. At Site A, the N-value (1.5 m, in the shallow sand) and q_c (13.0 m) were taken at different depths; the CPT depth falls within the depth range of the sandy and organic clay layer (4.5–13.0 m), and the CPT report remarks low bearing capacity and submerged foundation conditions there, so the Site A ratio compares different strata. At Site C, the N-value (13.5 m) and the CPT value (1.75 m) were taken at different depths, and the recommended pile founding depth below the clay is 14–15 m. Some CPT data (Site D) were read from graphs, and one q_c value (Site C) was back-calculated from the reported capacity; consultants used different formats and units, which required conversion. The reports do not state whether the N-values were energy-corrected, whereas Danziger et al. [21] report q_c/N_{60}, so the comparison with that value is approximate. In the SPT-based calculations the unit weight was taken as 18 kN/m^3 and groundwater was not considered, which may overestimate capacity where the water table is high. A uniform footing was assumed for comparability, and full foundation design and settlement were not considered.

5 Conclusion

This study assessed the validity of published SPT–CPT correlation ratios for reclaimed soils at six sites in Lagos Island. The main findings are:

- Subsoil conditions varied from sand only (Sites B and F) to clay or peat layers 1.5–23 m thick (Sites A, C, D and E).
- SPT-based allowable bearing capacity ranged from 237.5 to 404.5 kPa and CPT-based capacity from 245.2 to 653.8 kPa; the two agreed within +3.2% at Site A but differed by up to +131.8% at Site B.
- The site-derived q_c/N had a mean of 0.559 MPa, a range of 0.245–0.823 MPa, a coefficient of variation of 40.3% and a 95% confidence interval of 0.323–0.795 MPa; only one of six sites lay within the published range, although a one-sample t-test did not detect a significant difference between the mean and the Danziger et al. value ($p = 0.13$).
- Published generic SPT–CPT correlation ratios are therefore not reliable for predicting the bearing capacity of reclaimed soils in Lagos Island, since only one of the six sites fell within the published range. To the authors' knowledge, this is the first locally derived q_c/N ratio for these soils and the first documented evidence of this.

Based on these findings it is recommended that:

- Both SPT and CPT should be carried out; the cost of the additional test is small compared with the cost of over-designing a foundation or of repairing or reconstructing an under-designed one.
- Regulatory bodies such as the Lagos State Materials Testing Laboratory and the Council for the Regulation of Engineering in Nigeria (COREN) should consider adopting these locally derived values.
- Site-specific studies should be conducted before generic ratios are trusted anywhere in Lagos Island.
- Where site-specific data are genuinely unavailable, the mean (0.559 MPa) may serve as the best single estimate for general planning, feasibility and preliminary design; the lower bound (0.323 MPa) should be preferred when converting N to q_c for a conservative estimate at final design; and both bounds (0.323–0.795 MPa) should be used for a sensitivity check. This range is a fallback, not a replacement for site-specific testing.

Further studies should (i) use more sites for a statistically more robust ratio; (ii) examine other parts of Lagos, including the mainland and other Local Government Areas; (iii) explore other correlation methods and parameters such as settlement prediction; and (iv) investigate the relationship between anticipated structural load and foundation type on reclaimed soil.

Nomenclature

- B: footing width (m)
- N: SPT N-value (blows per 300 mm)
- D_f: founding depth (m)
- N_{60}: energy-corrected N-value
- γ: unit weight (kN/m^3)
- φ: friction angle (°)

- q_c: CPT cone resistance
- f_s: CPT sleeve friction
- q_u, q_a: ultimate and allowable bearing capacity
- N_c, N_q, N_γ: bearing capacity factors
- FS: factor of safety
- CoV, SEM: coefficient of variation, standard error of the mean
- CI: confidence interval
- SPT, CPT: standard and Cone Penetration Tests

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Declarations

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