Geotechnical Characterization and Bearing Capacity Evaluation for a Proposed Three-Storey Building at Polaku Community, Yenagoa, Nigeria

Avery, Tonipre Thompson; Ogunmakinwa Segun;
Department of Geology, Federal University Otuoke, Bayelsa State

Asano Nelson Omarijivwie
Southern Delta University

Abstract
Reliable foundation design in coastal and deltaic terrains requires detailed characterization of subsurface conditions due to the prevalence of weak, compressible soils. This study presents the results of a site-specific geotechnical investigation conducted for a proposed three-storey building at Polaku Community, Gbarian Clan, Yenagoa LGA, Bayelsa State, within the Niger Delta. Three boreholes were drilled to depths of 24–25 m using rotary wash boring, and Standard Penetration Tests (SPT) were performed at 3 m intervals. Subsurface stratigraphy revealed three (3) principal units typical of deltaic environments: soft clay (0–6 m), medium dense sand (6–12 m), and dense to very dense sand/gravel (below 12 m). SPT N-values ranged from 4–7 in the upper clay layers to over 80 in the deeper granular strata, indicating significant improvement in stiffness and relative density with depth. Undrained shear strengths for clays derived from Skempton correlations ranged from 16–28 kPa, while friction angles for sands (based on SPT correlations) ranged from 31.6° to 42°. Ultimate and allowable bearing capacities were computed using Terzaghi and Meyerhof formulations. Shallow cohesive layers yielded low allowable pressures (27–48 kPa), unsuitable for conventional shallow footings, whereas deeper sand layers produced significantly higher allowable capacities (245–979 kPa), sufficient to support multi-storey structures. Comparative evaluation with regional studies confirms that foundations bearing on the deeper dense sand layer will ensure safe performance. The study concludes that while near-surface soils require improvement or avoidance, the deeper granular strata provide competent bearing material for the proposed structure.

Keywords: Geotechnical investigation; Niger Delta soils; Standard Penetration Test (SPT); Bearing capacity; Soil stratigraphy; Foundation design; Polaku–Yenagoa.

1. Introduction

Site-specific geotechnical investigations are essential to determine subsurface conditions, engineering soil properties, and to guide foundation design, thereby mitigating the risk of settlement, bearing failure, or differential movement. Coastal and deltaic regions such as the Niger Delta present unique geotechnical challenges due to soft clay, compressible silts, and variable stratigraphy (Ezenwaka et al., 2014). Shallow foundations on weak soils often experience excessive settlement, necessitating detailed site-specific investigation.

This study was commissioned by J'Marvy Merchandises for a proposed three-storey building at Polaku Community, Gbarian Clan, Yenagoa LGA, Bayelsa State, Nigeria. The primary objective of the investigation was:

1. To drill three boreholes to a sufficient depth (maximum 25 m) to identify the bearing capacity of the strata and,
2. To perform, Standard Penetration Test (SPT) in-situ test.

DOI: https://doi.org/10.5281/zenodo.17875394

The investigation outcomes will support safe and reliable foundation design for the proposed structure.

2. Geological Setting

2.1 National Geological Framework

Nigeria's geology comprises three main litho-petrological components: the Precambrian Basement Complex (migmatite-gneiss complex, schist belts, and older granites), the Younger Granites (Jurassic ring-complexes), and sedimentary basins (Cretaceous to Tertiary), including the Niger Delta Basin.

2.2 Local Geology

The site lies in the Niger Delta Complex region and is characterized by alluvial, fluvio-deltaic, or mangrove-swamp sediments with alternating layers of clay, silt, and sand. Such soils are often highly compressible and may exhibit low bearing capacity near the surface (Teme & Nwankwoala, 2023). Boreholes BH01–BH03 were drilled to capture variability in soil properties up to 25 m depth. These recent sediments reflect the deltaic depositional environment, and a reconnaissance survey and review of available geological data support this local stratigraphy.

3. Methodology.

3.1 Field Investigation

Three (3) boreholes were drilled by rotary wash boring (water circulation) to a depth sufficient to intercept bearing strata (up to 25 m). The drilling rig used drill rods, vertical circulation of drilling water or mud, casing as required for unstable soils, and cuttings removal via annular flow to a settling pit or mud tank. At selected depths (3 m intervals), the boreholes were cleaned, and SPT was conducted using a thick-walled split-spoon sampler (outside diameter 5 cm, inside diameter 3.5 cm, length 65 cm), which was driven by a 63.5 kg hammer falling 76 cm. The tube was driven 15 cm, and the number of blows for the second and third 15 cm intervals (i.e., penetration from 15 cm to 45 cm) was summed to give the N-value. If 50 blows did not drive 15 cm, the penetration after 50 blows was recorded as the N-value.

3.2.Bearing Capacity Estimation:

Test results were then used to derive soil strength and parameters, to assess bearing capacity, and to provide foundation recommendations.

Empirical correlations using SPT, N-values with φ (angle of internal friction), applicable for granular soils (sands, silty sands, gravels), and with Su (undrained shear strength), appropriate for cohesive soils (clays), with a factor of safety of 3 applied in line with typical engineering practice **(Das, 2013)**. Ultimate bearing capacity for shallow strip footings on undrained clay was estimated using Terzaghi's bearing capacity **formula (Terzaghi &Peck 1948, Meyerhof 1956,1974, Skembpton 1957)**

Skempton formula (1957): Su = kN equ. (1)

Where:

3 k varies from 3 to 6 depending on plasticity,

Typical values of k for clays:

Very soft clay → k = 2–3

Soft clay → k = 3–4

Medium – stiff clay → k = 4–5

Very stiff clay → k = 5–6 and,

4 **N = (N_{60})** the SPT N-value corrected for hammer energy (to 60% energy efficiency).

N_{60} = N (Em ÷ 60) equ. (2)

Where: Em = measured field hammer energy (% efficiency), and 60% = reference energy defined by Skempton.

SPT N-value depends on many field factors:

- Hammer efficiency
- Borehole diameter
- Rod length
- Sampler type

To standardize results, Skempton recommended using **energy-corrected N** (now called **N_{60}**):

Once φ or Su is obtained:

For sand (using Terzaghi bearing capacity equation):

Ultimate Bearing Capacity (q_{ult}) = $1/2(\gamma B N\gamma) + qNq$ equ. (3)

Where Nq and Nγ depend on φ obtained from SPT correlations.

For clay (using Terzaghi's formula for φ = 0):

$q_{ult} = 5.14Su$ equ. (4)

Since Su comes from the SPT correlation, the bearing capacity becomes directly dependent on the N-value.

DOI: https://doi.org/10.5281/zenodo.17875394

Typical correlation (Meyerhof 1956):

- Loose sand: N = 4–10 → φ = 28°–32°
- Medium dense: N = 10–30 → φ = 30°–36°
- Dense: N > 30 → φ = 36°–41°

Direct SPT-to-Bearing Capacity Correlations by Peck, Hanson & Thornburn (1974)

Table 1: Approximate allowable bearing pressure (qa) values

SPT N (corrected)	Soil Consistency	qa (kN/m²)
0–4	Very soft	<50
4–10	Soft	50–100
10–20	Medium	100–200
20–40	Stiff	200–400
>40	Very stiff	400–600+

3.4.Comparison with local Nigerian studies.

Relevant Nigerian geotechnical research was reviewed to contextualize the findings. For example, a study on the shallow bearing capacity of soils in the Lekki Peninsula (Lagos) found shallow bearing capacities of 55 kPa on weak sands and urged raft or piled foundations (Arije & Adigun, 2020). Another investigation in Bayelsa State (Opolo and Amassoma) using MASW and SPT reported allowable bearing capacities of 60–172 kPa in competent layers (Macquen, Eteh & Oborie, 2024). These comparative results help benchmark our findings.

4.0.Results and Discussion.

This section presents the integrated results of Standard Penetration Tests (SPT) and soil classification from three boreholes drilled at the proposed project site. The analyses highlight the geotechnical behavior of the subsurface soils, with emphasis on their engineering significance for foundation design.

4.1.Standard Penetration Test (SPT) Results.

The SPT N-Values provide an index of relative density for granular soils and consistency for cohesive soils, and indicate variable soil conditions: Soft clay near surface (N = 4–6) is highly compressible and weak, stiff clay (N = 12–28), dense sand/gravel at depth (N = 25–81), is competent for foundation support. (**Table 2)**

- BH01: N-values increase from 5–6 at 0 – 6 m (soft clay/silt) to greater than 50 at 12–21 m (dense sand/gravel).
- BH02: N-values moderate, 4–32, indicating weak to medium stiff clay and sand.
- BH03: N-values 4–28, moderate clay/silty sand.

Interpretation:

- Upper clay layers exhibit low to medium N-values, indicating soft to medium stiffness suitable for shallow foundations only with proper treatment.
- Deeper sand layers show high N-values, indicating adequate bearing capacity for foundation support.

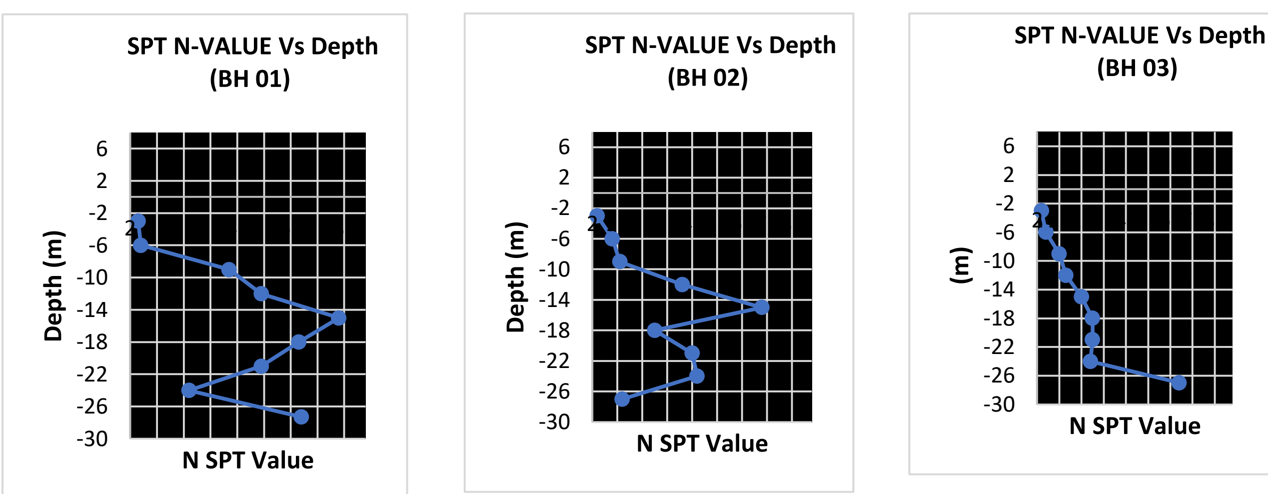
The increase in N-value with depth confirms densification and consolidation of soils.

DOI: https://doi.org/10.5281/zenodo.17875394

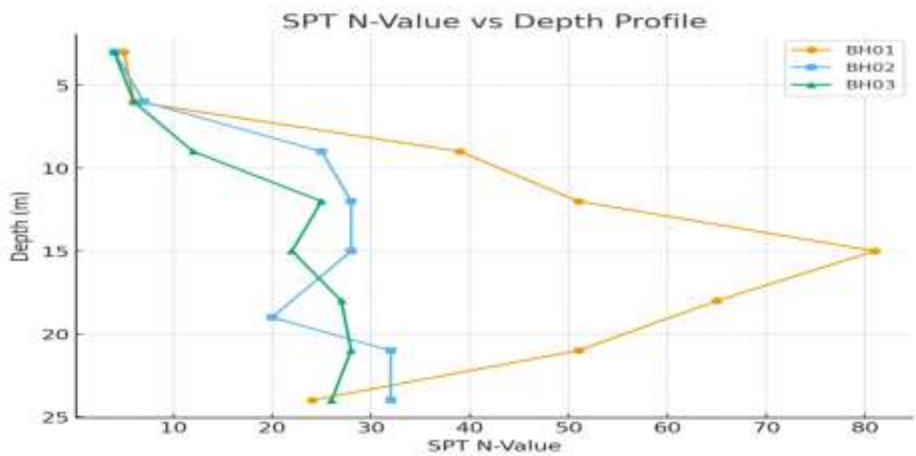
Table 2: SPT Results.

Borehole	Depth (m)	N-Value	Soil Type (Interpretation)
BH01	3	5	Soft clay
BH01	6	6	Soft clay
BH01	9	39	Dense sand
BH01	12	51	Dense sand
BH01	15	81	Very dense sand/gravel
BH01	18	65	Dense sand
BH01	21	51	Dense sand
BH01	24	24	Medium sand
BH02	3	4	Soft clay
BH02	6	7	Soft clay
BH02	9	25	Medium sand
BH02	12	28	Medium sand
BH02	15	28	Medium sand
BH02	19	20	Medium sand
BH02	21	32	Dense sand
BH02	24	32	Dense sand
BH03	3	4	Soft clay
BH03	6	6	Soft clay
BH03	9	12	Medium clay/sandy clay
BH03	12	25	Medium sand
BH03	15	22	Medium sand
BH03	18	27	Medium sand
BH03	21	28	Medium sand
BH03	24	26	Medium sand

FIGURE 1: Plot of SPT N-Values against Depth Profile.



DOI: https://doi.org/10.5281/zenodo.17875394



4.2.Subsurface Stratigraphy Based on SPT and Visual Classification:

Based on field logs and SPT data, four principal layers or soil profiles were consistently identified across the site. Three boreholes (BH1, BH2, and BH3) were drilled to a maximum depth of 25 m. The boreholes encountered predominantly cohesive soils (clay and silty clay) in the upper to mid-depths, underlain by granular soils (sandy silt and sand) at greater depths. The stratigraphy of each borehole is summarized below:

BH1:
- 0–6 m: Topsoil and loose silty clay
- 6–12 m: Medium sand
- 12–25 m: Medium to very dense sand

BH2:
- 0–6 m: Topsoil and soft clay
- 6–12 m: Medium sand
- 12–25 m: Dense sand

BH3:
- 0–6 m: Topsoil and soft clay
- 6–12 m: sandy clay to medium sand
- 12–25 m: Medium dense sand

The variation in depth and consistency indicates local heterogeneity in depositional processes, typical for alluvial or deltaic environments.

Three (3) profile sequences or layers were identified or observed; they are;

Layer A – Soft Cohesive Layer (0-6 m, highly compressible clays):

Across all the boreholes, the upper six meters (6 m) is dominated by very soft, highly compressible clays, with SPT N-values ranging between 4 and 7:
- BH01: N = 5–6
- BH02: N = 4–7
- BH03: N = 4–6

These low N-values indicate very soft to soft consistency, high natural moisture content, and low undrained shear strength; conditions typical of shallow deltaic sediments.

Engineering Significance:
- High compression and consolidation settlement.
- Low bearing capacity unsuitable for shallow foundations.
- Potential for negative skin friction on piles due to consolidation of the surrounding soft soil.
- Requires extension of foundations to deeper competent layers.

Layer B – Dense Non–Cohesive Layer (Intermediate Transition Zone, 6–12 m: Silty Clay / Sandy Clay / Medium Sand):

Between 6–12 m, the soils transition into silty sands, sandy clays, and medium dense sands:
- BH01: Sudden increase at 9 m (N = 39 → dense sand)
- BH02: N = 25–28 → medium dense sands

DOI: https://doi.org/10.5281/zenodo.17875394

- BH03: N = 12–25 → sandy clay to medium sand

The rapid increases in N-values suggest improved soil competence and a shift to granular materials with higher shear strength and lower compressibility.

Engineering Significance:
- Potential for moderate bearing capacity.
- Reduced settlement risk.
- Suitable strata for socketed friction piles.
- Still not ideal for high shallow foundation loads.

Layer C – Dense to Very Dense Non–cohesive Layer (Deep Competent Layer 12–24 m):

This zone shows the highest N-values, indicating competent load-bearing strata:
- BH01: N = 51–81 (dense to very dense sand/gravel)
- BH02: N = 20–32 (medium to dense sand)
- BH03: N = 22–28 (medium sand)

BH01 exhibits the strongest substratum with N-values as high as 81, indicating very dense sand or gravelly sand with excellent load-carrying potential. BH02 and BH03 show medium to dense sands with reliable foundation support characteristics.

Engineering Significance:
- Most suitable zone for end-bearing piles.
- High shear strength.
- Minimal settlement.
- Excellent lateral resistance for pile or deep foundation systems.

Hence, the overall soil profile shows a gradual transition from soft to stiff cohesive soils, followed by dense granular layers. This stratification indicates that while the upper layers may require improvement or foundation adjustment, the deeper layers provide adequate bearing capacity for the proposed three-story structure.

TABLE 3a: BOREHOLE LOG 1

Project Information

Name:

Consultant: T.T Avery

Drilling Information

Borehole No: <u>BH 01.</u> **Coordinates:**

Depth of borehole: <u>26.5 meters.</u>

Water level: <u>Encountered at 3.2m.</u>

Date:

Depth (m)	N 15cm	N 15cm	N 15cm	N cont.	Sample No.	*Soil Description*	Geology	RQD	TCR	Remarks
2.5	Before SPT					ORGANIC CLAY, Dark Grayish Brown				
3	3	2	3	5		ORGANIC CLAY OR SILT, Dark Grayish Brown, Medium with low plasticity.				
6	4	3	3	6		Fine SAND with silt, Pale Yellow, Loose, poorly graded.				
9	9	13	26	39		Fine SAND with silt, Light Yellowish Brown, Dense, poorly graded.				
12	3	16	35	51		Fine SAND, Olive Yellow, Very Dense, poorly graded.				

DOI: https://doi.org/10.5281/zenodo.17875394

15	**13**	**20**	**60**	**80**		**Fine SAND, Brownish Yellow, Very Dense, poorly graded.**				
18	**18**	**27**	**38**	**65**		**Fine SAND with silt, Olive Yellow, Very Dense, poorly graded.**				
21	**12**	**21**	**30**	**51**		**Medium SAND, Light Yellowish Brown, Very Dense, poorly graded and angular.**				
24	**8**	**11**	**13**	**24**		**Medium SAND, Light Yellowish Brown, Dense, poorly graded and angular.**				

TABLE 3b: BOREHOLE LOG 2.

Project Information

Name:

Consultant: T.T Avery

Location: Polaku Community

Drilling Information

Borehole No: BH 02. Coordinates:

Depth of borehole: 24.0 meters.

Water level: Encountered at 2.5m.

Date:

Depth (m)	N 15cm	N 15cm	N 15cm	N cont.	Sample No.	*Soil Description*	Geology	RQD	TCR	Remarks
3	**2**	**2**	**2**	**4**		**CLAY, Dark Grayish Brown, soft with low plasticity**				
6	**1**	**3**	**4**	**7**		**CLAY, Very Dark Grayish Brown, firm with low plasticity**				
9	**13**	**15**	**10**	**25**		**Fine SAND with traces of silt, Light Olive Brown, Very Dense, well graded, subangular with non-plasticity.**				
12	**6**	**13**	**15**	**28**		**Fine SAND with traces of silt, Light Olive Brown, Dense, poorly graded, subangular to angular**				
15	**7**	**12**	**16**	**28**		**Fine SAND with traces of silt, Light Yellowish Brown, Dense, poorly graded with non-plasticity.**				
19	**6**	**10**	**10**	**20**		**Fine SAND with traces of silt, Yellowish Brown, Medium Dense, poorly graded with non-plasticity.**				
21	**11**	**15**	**17**	**32**		**Fine SAND with traces of silt, Light Yellowish Brown, Dense, poorly graded.**				
24	**13**	**16**	**16**	**32**		**Fine SAND with traces of silt, Light Olive Brown, Dense, poorly graded with non-plasticity.**				

DOI: https://doi.org/10.5281/zenodo.17875394

TABLE 3c: BOREHOLE LOG 3.

Project Information	Drilling Information
Name:	**Borehole No**: BH 03 **Coordinates:**
Consultant: T.T Avery	**Depth of borehole**: 27.5 meters.
Location: Polaku Community	**Water level**: Encountered at 3.2m.
	Date:

4.3 Derived Parameters and Allowable Bearing Pressure Estimates.

The derived bearing capacity parameters were estimated using Terzaghi's bearing capacity formula

Depth (m)	N 15cm	N 15cm	N 15cm	N cont.	Sample No.	*Soil Description*	Geology	RQD	TCR	Remarks
2.7	Before SPT									Sand Fill
3	1	2	2	4		Silty CLAY, Dark Grayish Brown, Soft.				
6	3	4	2	6		Silty CLAY, Dark Grayish Brown, Firm.				
9	4	5	7	12		Silty SAND, Dark Grayish Brown, Medium Dense, poorly graded.				
12	7	10	15	25		Silty SAND, Grayish Brown, Medium Dense, poorly graded.				
15	5	10	12	22		Medium to Coarse SAND with Silt, Yellowish Brown, Medium Dense, poorly graded and angular.				
18	4	15	12	27		Medium to Coarse SAND, Grayish Brown, Medium Dense, poorly graded and angular.				
21	10	13	15	28		Fine SAND with Silt, Yellowish Brown, Medium Dense, poorly graded.				
24	12	13	13	26		Fine SAND, Yellowish Brown, Medium Dense, poorly graded.				

(Terzaghi &Peck 1948, Meyerhof 1956,1974, Skempton 1957) from equations 1,2, 3, and 4. And results are summarized in Table 4 below;

DOI: https://doi.org/10.5281/zenodo.17875394

Table 4: Results of Bearing Parameter (per depth)

Borehole	Depth (m)	Soil type	N_{60}	k (clay)	S_u (kPa)	φ (°)	N_q	N_γ	q_{ult} (kPa)	q_{allaw} (kPa, FS=3)
BH01	3	Soft clay	5	4.0	20.000	—	—	—	102.800	34.267
BH01	6	Soft clay	6	4.0	24.000	—	—	—	123.360	41.120
BH01	9	Dense sand	39	—	—	35.02	46.208	33.379	1034.448	344.816
BH01	12	Dense sand	51	—	—	37.18	56.606	43.936	1404.337	468.112
BH01	15	Very dense sand/gravel	81	—	—	42.00	93.706	85.374	2936.606	978.869
BH01	18	Dense sand	65	—	—	39.70	72.972	61.583	2043.714	681.238
BH01	21	Dense sand	51	—	—	37.18	56.606	43.936	1404.337	468.112
BH01	24	Medium sand	24	—	—	32.32	36.460	24.067	718.658	239.553
BH02	3	Soft clay	4	4.0	16.000	—	—	—	82.240	27.413
BH02	6	Soft clay	7	4.0	28.000	—	—	—	143.920	47.973
BH02	9	Medium sand	25	—	—	32.50	37.020	24.585	735.907	245.302
BH02	12	Medium sand	28	—	—	33.04	38.772	26.217	790.546	263.515
BH02	15	Medium sand	28	—	—	33.04	38.772	26.217	790.546	263.515
BH02	19	Medium sand	20	—	—	31.60	34.326	22.117	654.103	218.034
BH02	21	Dense sand	32	—	—	33.76	41.280	28.593	870.731	290.244
BH02	24	Dense sand	32	—	—	33.76	41.280	28.593	870.731	290.244
BH03	3	Soft clay	4	4.0	16.000	—	—	—	82.240	27.413
BH03	6	Soft clay	6	4.0	24.000	—	—	—	123.360	41.120
BH03	9	Medium clay / sandy clay	12	4.5	54.000	—	—	—	277.560	92.520
BH03	12	Medium sand	25	—	—	32.50	37.020	24.585	735.907	245.302
BH03	15	Medium sand	22	—	—	31.96	35.371	23.068	685.519	228.506
BH03	18	Medium sand	27	—	—	32.86	38.176	25.659	771.836	257.279
BH03	21	Medium sand	28	—	—	33.04	38.772	26.217	790.546	263.515
BH03	24	Medium sand	26	—	—	32.68	37.592	25.115	753.628	251.209

Notes on table columns.

- **k** and **Su** shown only for layers interpreted as clay.
- **φ, N_q, N_γ, q_{ult}, q_{allaw}** shown for cohesionless layers (sands).
- All **q_{ult}**, and **q_{allaw}** are in kPa, and **q_{allaw}** uses a factor of safety (F.S) = 3.

4.4.Strength and Compressibility.

SPT test results confirmed the increase in stiffness with depth (Table 2). The results placed the clays in the "soft" and "medium stiff" classes according to typical industry strength classification.

Near-surface (3–6 m) layers at all boreholes are soft clay (N_{60} = 4–7). Su is approximately 16–28 kPa, and q_{allow} equals 27–48 kPa — very low bearing capacity and high primary consolidation settlement potential. From about 9 m downward, the ground changes to sands of increasing density. Medium sands give, Allowable bearing capacity (q_{allow}) ranging from 218 – 263 kPa (BH02, BH03 mid-depths). Dense sands give q_{allow} ranging from 344 – 681 kPa (BH01 deeper layers). Very dense sand/gravel at BH01, 15 m has q_{allow} of 979 kPa (excellent for heavy loads).
The implication is that **shallow foundations seated on the near-surface clays are risky** for

DOI: https://doi.org/10.5281/zenodo.17875394

anything but very-light loads unless improved. Sands at depth provide much higher allowable pressures and are preferred founding strata

4.5 Non-Cohesive Layers

The sand layers (layers C and D) indicate higher density and therefore better bearing potential, but they are underlaid by cohesive clay layers, which may govern overall performance for shallow foundations. The depth to the denser material (6 m and below) suggests that deeper foundation elements or load transfer mechanisms may be beneficial.

Generally speaking, the project site shows significant heterogeneity in soil properties. In weak clay layers (as shown in BH02 and BH03), the very low undrained shear strength (s_u 16 kPa) means shallow foundation allowable bearing pressures must be conservative (27.4 kPa) to avoid bearing capacity failure or large settlements. In contrast, deeper competent layers (e.g., BH01 and BH03 at 6 m) allow higher bearing pressure (41.1 kPa), but settlement potential must still be addressed.

Comparative Nigerian studies underscore this caution: e.g., Arije & Adigun (2020) in Lagos found shallow bearing capacities around 55 kPa but recommended raft or piled foundations. Macquen et al. (2024) in Bayelsa (Opolo/Amassoma) found allowable 60–172 kPa in competent layers — highlighting that competent strata must be verified in the field. Our site thus fits this pattern: shallow, weaker clay, deeper competent layers, requiring either conservative shallow footings or deeper foundations.

Also, Nigerian roads/structure investigations (e.g., James & Emem, 2018; Adunoye, Kareem & Odetola, 2023) show that lateritic soils and tropical clays often require soil improvement or deep support. The consolidation indices and low σ′p in our site suggest we should also consider settlement control as integral, not just bearing capacity.

5. Recommendations

5.1 Structure Type Consideration

The site is generally suitable for development, but given the subsurface conditions (soft to medium stiff clay near the surface, low N-values, moderate compressibility), the following foundation design considerations apply:

For a light structure (e.g., single-storey houses, small shops, light loads up to ~150 kPa), a properly designed shallow foundation (spread/raft) may be acceptable, provided that the design uses the weaker of the two borehole (BH02 and BH03) parameters, and settlement risk and differential settlement are managed. For shallow (strip/pad) footings at shallow depths (<2 m), do not bear directly on near-surface clays (3–6 m soft clay q_{allow} = 27–41 kPa) unless the structure is *very* light and settlement tolerance is high.

Preferably, shallow footings should be seated on medium sand horizons at 9 – 12 m (q_{allow} = 245–263 kPa for many locations BH02/BH03). That gives ample capacity for typical light building loads.

For a moderate to heavy multi-storey structure, heavy industrial loads, large tanks — loads may require ≥300–1000 kPa, the shallow subsoil conditions are **not ideal** without ground improvement or deep foundation, and the risk of settlement, bearing failure, or differential movement becomes significant.

Piled foundations (bored cast-in-place or driven piles) **socketed into the very dense sand/gravel at BH01, 15 – 18 m** (q_{allow} 681–979 kPa indicates excellent end-bearing potential) is recommended.

Typical approach:

- Piles should be designed to mobilize end-bearing in the very dense layer (socket length depending on pile type).
- Use a combination of **end-bearing + shaft friction** if required.
- Pile load tests should be performed to confirm capacity and settlement at working load.

6.0.Summary and Conclusion

6.1.Summary

A detailed geotechnical investigation was conducted to characterize subsurface conditions and estimate the allowable bearing capacity for the proposed three-storey building at Polaku Community, Bayelsa State. The investigation involved drilling three boreholes to depths of up to 25 m and carrying out Standard Penetration Tests at 3 m intervals. Geological information confirmed that the site is underlain by young

DOI: https://doi.org/10.5281/zenodo.17875394

Niger Delta alluvial sediments prone to soft clay, high compressibility, and variable stratigraphy.

Field and laboratory interpretations revealed four distinct geotechnical layers:

1. Soft clay (0–6 m): characterized by very low SPT N-values (4–6) and low undrained shear strength (Su = 16–28 kPa), resulting in very low allowable bearing pressures (27–48 kPa).
2. Medium dense sand (6–12 m): improvement in density, with N-values of 20–28 and allowable bearing capacities of 218–263 kPa.
3. Dense to very dense sand with gravel (12–25 m): high N-values (51–81) and high allowable bearing pressures (344–979 kPa), representing highly competent founding material.

The stratigraphy indicates a typical deltaic profile, with weak upper layers overlying competent sand units at depth. The shallow clays are unsuitable for conventional shallow foundations without improvement, due to low strength and high settlement potential. Comparisons with previous Nigerian studies (Lekki, Opolo, Amassoma) further support the need for careful consideration of foundation depth and soil variability in deltaic terrains.

6.2.Conclusion

The geotechnical assessment demonstrates that the subsurface conditions at the project site vary significantly with depth, transitioning from soft, compressible clays near the surface to dense, competent sands below 12 m. The upper cohesive layers exhibit low SPT N-values and low allowable bearing pressures, making them unsuitable for supporting moderate to heavy structural loads without ground improvement or load-spreading systems such as rafts.

However, the deeper granular layers offer excellent bearing capacity and reduced settlement risk, making them appropriate for deeper foundations such as pile foundations, deep pads, or raft foundations placed at greater depth. For a three-storey building, safe and serviceable performance will require either:

• Deep foundations (piles) founded in dense sand layers, or

• A shallow raft foundation with soil improvement if economic and feasible.

The study concludes that while the site is geotechnically viable for development, the foundation design must account for weak near-surface soils, differential stratigraphy, and settlement concerns typical of Niger Delta environments. Proper adaptation of the foundation type to the identified soil profile will ensure structural stability and longevity.

References:

Adunoye, G. O., Kareem, S. P., & Odetola, H. M. (2023). Experimental investigation on the bearing capacity of selected soils in Ayedaade Local Government Area, Osun State, Nigeria. *International Journal of Civil Engineering, Construction and Estate Management*, 11(1),45–57.

Ahaneku, C. V., Ezenwaka, K. C., Ugboaja, A., & Ede, T. A. (2014). "Geotechnical Investigation for Design and Construction of Civil Infrastructures in Parts of Port Harcourt City of Rivers State, Southern Nigeria". *International Journal of Engineering Science*, 3(8), 74–82. ResearchGate

Akpokodje, E.G. (2001). *Geotechnical properties of soils of the Niger Delta*. Journal of Mining and Geology, Vol. 37(1), pp. 61–68.

Alshameri B., Madun A. and Bakar I. (2017), "Comparison of the Effect of Fine Content and Density towards the Shear Strength Parameters", Geotechnical Engineering Journal of the SEAGS & AGSSEA, Vol. 48 No. 2 June 2017 ISSN 0046-5828.

Arije, Y. K., & Adigun, A. O. (2020). Evaluation of shallow foundation soils around Lagos using results from Cone Penetration Test. *International Journal of Engineering and Science (IJES)*, 9(6), 21–26.

Bowles, J. E. (1996). *Foundation Analysis and Design* (5th ed.). McGraw-Hill.

Brady, N.C., & Weil, R.R. (2010). *The Nature and Properties of Soils*. 14th ed.

Braja, M. Das& Khaled, Sobhan (2018) "principles of geotechnical engineering ", US, Cengage learning.

Briaud, J.L. Geotechnical Engineering: Unsaturated and Saturated Soils; John Wiley & Sons: Hoboken, NJ, USA, 2023.

British Standards Institution. (1990). *BS 1377-7:1990 Methods of test for soils for civil engineering purposes. Part 7: Shear strength tests (total stress)*. BSI.

DOI: https://doi.org/10.5281/zenodo.17875394

Coduto, D. P., Yeung, M. R., & Kitch, W. A. (2011). *Geotechnical Engineering: Principles and Practices*. 2nd Edition. Pearson.

Craig, R. F. (2004). *Soil Mechanics*. 7th ed. Taylor & Francis.

Das, B. M. (2010). *Principles of Geotechnical Engineering*. 7th ed. Cengage Learning.

Das, B. M. (2013). *Principles of Foundation Engineering* (7th ed.). Cengage Learning.

Ezenwaka, K. C., Ugboaja, A., Ahaneku, C. V., & Ede, T. A. (2014). Geotechnical investigation for design and construction of civil infrastructures in parts of Port Harcourt City of Rivers State, Nigeria. *The International Journal of Engineering and Science (IJES)*, 3(8), 74–82.

H.O. Nwankwoala, E. Oborie (2014), **Geo-technical Investigation and Characterization of Sub-soils in Yenagoa, Bayelsa State, Central Niger Delta, Nigeria,** Civil and Environmental Research ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol 6, No.7.

Hansen, J. B. (1970). *A revised and extended formula for bearing capacity*. Danish Geotechnical Institute.

Holtz, R. D., & Kovacs, W. D. (1981). *An Introduction to Geotechnical Engineering*. Prentice-Hall.

Ifeyinwa Pamela Dibia. (2024). "The Role of Geotechnical Investigations in Enhancing the Safety and Sustainability of Hydropower Projects". *Asian Journal of Geological Research*, 7(2), 88–98. journalajoger.com

Isah, C., Daku, S., & Yenne, E. (2016). Geotechnical investigations for infrastructural development: A case study of Daki Biyu District, Federal Capital Territory, Abuja, Central Nigeria. *[journal info]* (please supply full journal citation).

James, G. A., & Emem, P. E. (2018). Bearing capacity evaluation of lateritic soil stabilized with sand for use as subgrade. *International Journal of Civil Engineering and Technology (IJCIET)*, 9(11), 2620–2629.

Macquen, B. A., Eteh, D. R., & Oborie, E. O. (2024). Comparative analysis of foundation materials bearing capacity using MASW techniques in Opolo and Amassoma, Bayelsa State, Nigeria. *Asian Journal of Geological Research*, 7(3), 219–231.

Peter G. Nicholson. (2015). Soil Improvement and Ground Modification Methods.

"Geotechnical Investigation – an overview." *ScienceDirect Topics*. sciencedirect.com

Teme, S. C., & Nwankwoala, H. O. (2023). Geologic and geotechnical investigation for engineering design of foundation systems at the Federal University, Otuoke, Bayelsa State, Nigeria. *[journal info]* (please supply full journal citation).

Terzaghi, K., Peck, R. B., & Mesri, G. (1996). *Soil Mechanics in Engineering Practice* (3rd ed.). John Wiley & Sons.

Karl Terzaghi — bearing capacity theory and practical soil mechanics (Terzaghi & Peck, *Soil Mechanics in Engineering Practice*, 1948).

Meyerhof — modifications to bearing-capacity factors and shape/depth effects (papers 1951, 1963, later compendia).

Skempton — SPT interpretation and correlations for clays (1950s).

DOI: https://doi.org/10.5281/zenodo.17875394