

Engineering Geological Investigation of Shallow Foundation Conditions in Amasoma, Bayelsa State, Nigeria

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doi: <https://doi.org/10.37745/bjesr.2013/vol14n2111>

Published March 13, 2026

Citation: Ashioba, C., Komolafe, N. P., Nwankwoala, H. O. (2026) Engineering Geological Investigation of Shallow Foundation Conditions in Amasoma, Bayelsa State, Nigeria, *British Journal of Earth Sciences Research*, 14(2),1-11

Abstract: *An engineering geological investigation was conducted to evaluate the suitability of subsoil conditions for shallow foundation systems in Amasoma, Bayelsa State. The study focused on characterizing the near-surface soils, determining their geotechnical properties, and assessing their bearing capacity and settlement characteristics for safe and economical foundation design within the Niger Delta depositional environment. Laboratory results indicate that soils are predominantly soft to firm silty clay and clayey silt with intercalations of sandy layers. The Atterberg limit results reveal that the liquid limit ranges from 46.5% to 98.3%, the plastic limit ranges from 26.7% to 49.8% while the plasticity index values range from 23.0% to 48.5%. The cohesive soils (clays) are highly plastic (CH) in the Unified Soil Classification System (USCS) designation. The natural moisture content ranges from 39.8% to 91.3%. The particle size distribution analysis reveals that the sand is fine to medium to coarse grained and in a medium dense state of compaction and based on its coefficient of uniformity and gradation classifies as poorly graded (SP) by the USCS designation. The moisture content of the sand ranges from 8.9% to 13.0% while the bulk unit weight ranges from 19.6KN/m³ to 20.3 KN/m³. The angle of shearing resistance ranges from 26⁰ to 33⁰, suggesting moderate shear strength characteristics. The result of the undrained shear strength of the clay ranges from 16Kpa and 19Kpa. The clay is very soft to soft and exhibit medium to high moisture content. The strength test result indicates a material of low undrained shear strength, the coefficient of consolidation, C_v of the clay soil samples varies between 1.13m²/year and 2.87 m²/year. The coefficient of volume compressibility, M_v, for the same materials varies between 0.23 m²/MN and 0.833 m²/MN, generally indicating clay layers of high to very high compressibility. Raft foundation is best suited for these weak, soft foundation materials for lightly loaded buildings with proper soil improvement.*

Keywords: geotechnical properties, atterberg limit, particle size, compressibility

INTRODUCTION

Engineering geology plays a vital role in civil engineering projects by ensuring that geological and geotechnical conditions of a site are properly understood before construction begins. In riverine and deltaic environments, subsurface materials are often weak, highly compressible, waterlogged, and prone to settlement. Without adequate site investigation, structures such as building, bridge, highway, railway, runway, embankment etc., may experience differential settlement, cracking, tilting, or even failure. (Ashioba and Udom., 2023).

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Amasoma is located within Bayelsa State in the core of the Niger Delta region. The Niger Delta is characterized by recent alluvial deposits consisting mainly of soft clays, silt, peat, and loose sands. These sediments are typically poorly consolidated and often exhibit low bearing capacity and high compressibility. Additionally, the area experiences high annual rainfall and a shallow groundwater table, which significantly influences soil behaviour and foundation performance. Rapid population growth and infrastructural development in Amasoma, especially due to the presence of educational institutions and expanding residential areas have increased the demand for stable foundations and durable road networks. However, many construction projects in the area are executed with limited geotechnical investigation, resulting in structural defects such as cracks in walls, pavement failure, and excessive settlement. (Ashioba and Nwankwoala, 2025).

Therefore, an engineering geological investigation of Amasoma is necessary to evaluate subsurface soil conditions, determine engineering properties, and provide recommendations for safe and cost-effective foundation design. This study aims to contribute to safer construction practices and sustainable infrastructure development in the area. (Ashioba et al., 2024; Oghenero *et al.*, 2014; Nwankwoala *et al.*, 2014; Ngah *et al.*, 2013).

MATERIALS AND METHODS

Description of the Study Area: The study area Amasoma is a town in Southern Ijaw Local Government Area of Bayelsa State is found within longitude $5^{\circ} 75' E$ and $6^{\circ} 06' E$ and latitude $4^{\circ} 05' N$ and $4^{\circ} 58' N$ (Fig. 1). The study area is in the Niger Delta tropical rain forest climate with high humidity and significant rainfall throughout the year. The area is dominated by mangrove vegetation and freshwater swamp forests. Drainage is controlled by numerous creeks, rivers, and tidal channels typical of the Niger Delta environment. Poor drainage conditions often lead to waterlogging and reduced soil bearing capacity. Basically the study area is accessible by a good road network. The study area is characterized by low-lying terrain, generally close to sea level. The area is predominantly flat, with elevations typically less than 20 meters above sea level. The location falls within the Niger Delta (Miocene-Recent) which occurs at southern part of Nigeria bordering the Atlantic Ocean. Stratigraphically, the Niger Delta comprises of the lower marine unit, the Akata Formation, the middle continental unit, the Agbada Formation and the upper continental sequence, the Benin Formation. However, the study area falls within the Benin Formation which is characterized by clay, sand and sandstones that are coarse grained (commonly very granular) to very fine grained. (Reyment, 1965, Short and Stauble, 1967). The main deposit encountered at the site is organic peaty materials, soft clay, silty clay and loose sands. These deposits are generally unconsolidated and water-saturated, resulting in low shear strength and high compressibility. The shallow groundwater table is a major geological characteristic influencing foundation design and construction practices in the area. There is severe drainage problem with seasonal and temporary flooding due to heavy rainfall and rise in groundwater table.

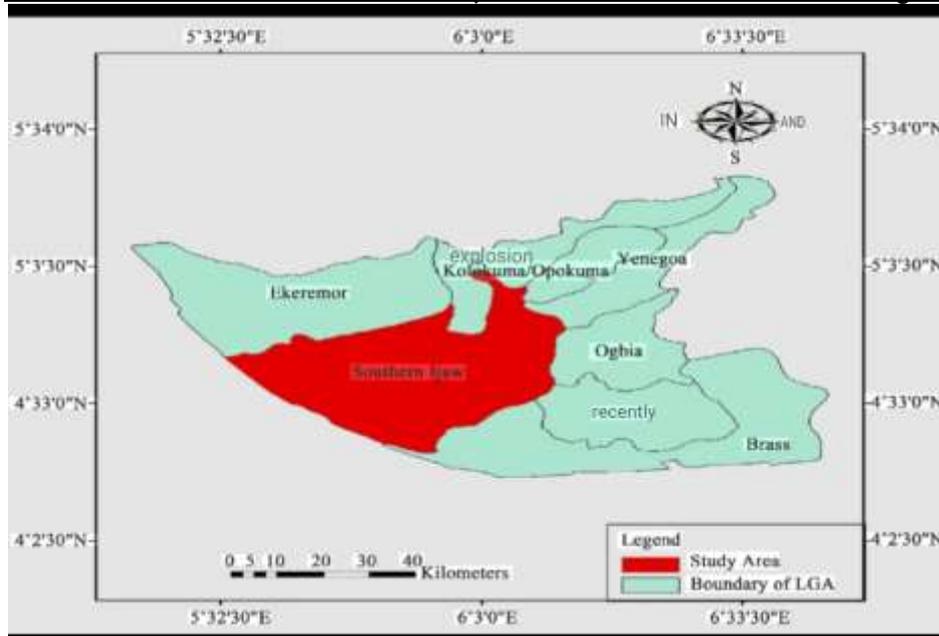


Fig. 1: Map of Bayelsa State showing the study location

Sample Collection: The investigation comprised mainly the drilling of two (2) number geotechnical boreholes in Amasoma in Southern Ijaw Local Government Area of Bayelsa State, with soil sampling, measurement of water table and conducting standard penetration tests. The boreholes were drilled using the percussion boring rig. The disturbed samples were taken at regular intervals and at change in soil type. The samples were used for a detailed and systematic description of the soil in each stratum in terms of its visual and tactile properties and for laboratory tests. The soil sampling was carried out in accordance with BS1377, with a minimum requirement set out in ASTM. Field measurements of groundwater showed that groundwater levels stood at 1.0m. The water levels in boreholes are subject to seasonal fluctuations.

Laboratory investigation: A series of classification, strength and compressibility tests were carried out in the laboratory. These tests were performed in accordance with British and ASTM standards. Details of the different tests are given below.

Moisture Content: Moisture content test was carried out in accordance with BS1377, on samples recovered from the boreholes. The moisture content was determined by drying selected moist/wet soil materials for at least 18 hours to a constant mass in a 110°C drying oven. The difference in mass before and after drying was used as the mass of the water in the test material. The mass of material remaining after drying was used as the mass of the solid particles. The ratio of the mass of water to the measured mass of solid particles was the moisture content of the material.

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Atterberg Limits: Atterberg limits were determined on soil specimens with a particle size less than 0.425mm. The Atterberg limit refers to arbitrary defined boundaries between the liquid limit and plastic states (liquid limit, W_L) and between the plastic and the brittle states (plastic limit, W_P) of fine-grained soils. The liquid limit is the water content at which a part of soil placed in a standard cup and cut by a groove of standard dimensions flow together at the base of the groove when the cup is subjected to 25 standard shocks. The one-point liquid test was carried out. Distilled water was added during soil mixing to achieve the required consistency. Plastic limit is the water content at which a soil can no longer be deformed by rolling into 3mm diameter threads without crumbling. The difference between the liquid limit and the plastic limit is the plasticity index, I_P .

Particle Size Analysis: Particle size analyses were performed by means of sieving. Sieving was carried out for particles that would be retained on a 0.075mm sieve, dry sieving was carried out by passing the soil sample over a set of standard sieve sizes and then shakes the entire units for few minutes with sieve shaker (machine).

Particle size is presented on a logarithmic scale so that two soils having the same degree of uniformity are represented by curves of the same shape regardless of their positions on the particle size distribution plot. The general slope of the distribution curve may be described by the coefficient of uniformity C_u , where $C_u = D_{60}/D_{10}$ and the coefficient of curvature C_c , where $C_c = (D_{30})^2 / D_{60} \cdot D_{10}$. D_{60} , D_{30} and D_{10} are effective particle sizes indicating that 60%, 30% and 10% respectively of the particles (by weight) are smaller than the given effective size. Reference test standard, BS1377, Part2, 1990.

Unit Weight: The unit weights were determined from measurement of mass and volume of the soil. The unit weight (KN/m^3) refers to the unit weight of the soil at the sampled water content, The dry unit was determined from the mass of oven-dried soil and the initial volume. . Reference test standard, BS1377, Part2, 1990.

Unconsolidated undrained Triaxial: Unconsolidated undrained triaxial compression tests were performed on cohesive samples, relatively undisturbed samples obtained from the open boreholes, with the objective of determining their undrained strength parameters, in accordance with BS1377, Part2, 1990

Direct Shear Test: The soil specimen is loaded into the shear box which split into two halves along a horizontal plane at its middle. The box is square with 60mm sides and 50mm high. It is made up of brass metal. It is placed inside a larger box-container and mounted on the loading frame. A proving ring is fitted to the upper half of the box to measure the shear force. The proving ring which butts against a fixed support records the shear force as the box moves and the shear displacement is measured with a dial gauge fitted to the container. Another dial gauge fitted to the top of the pressure pad measures the change in the thickness of the specimen. . Reference test standard, BS1377, Part1-2016.

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Oedometer Consolidation: Laboratory consolidation tests were carried out on cohesive soil specimens, relatively undisturbed sample with object of determining the compressibility properties of the soils, in accordance with BS 1377. The plot of void ratio (e) against effective pressure (P) for the samples tested presented in tables 1 and figure 4 together with calculated values of the coefficients of consolidation, (Cv) and coefficient of compressibility (Mv). Test results show that the samples are of predominantly high compressibility.

Soil Stratigraphy: The strata show that the site is predominantly clay both in boreholes BH1 and BH2. In BH1, the strata reveal a 3.50m thick formation of peaty clay from the riverbed underlain by fine sand to a depth of 5.20m. Underneath the fine sand a 24.80m thick stratum of grey peaty clay is encountered between 5.20 and 30.0m. From beneath this clay to the final depth of 45.0m of the investigation, is medium dense sand. In BH2, a 0.75m thick loose silty sand is observed from the riverbed. (The fact that the sand is loose reveals the ease with which it can be scoured). Beneath the 0.75m thick sand, clay is encountered to the depth of 5.0m. Between 5.0 and 6.0m depth, fine sand is encountered and from 6.0 and 32.50m, a 26.50m thick peaty clay is observed. From 32.5 to 45.0m fine to medium sand, with medium compaction, is encountered.

RESULTS AND DISCUSSION

Soft Clays: The engineering properties and behaviour of clay is of significant because of the dominant influence of the fines. The higher the liquid limit of clays and silts, the more compressible they become. The engineering properties of soil samples obtained from the laboratory analysis are presented in tables 1-5 and figures 2-6.

Determination of Characteristics values

Cautious Estimate for Characteristics Values: Schneider (1999) proposed the formula for the derivation of the characteristics mean value as: $X_{m,k} = X_m - 0.55$

Where:

$X_{m,k}$ = characteristics mean value.

X_m = arithmetic mean value of test result

S = the standard deviation of the sample.

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Table 1: Geotechnical properties of soil samples

Soil type	Soil parameters	X_m	S	X_{m-k}
Clay	Moisture Content (%)	61	17	52
	Bulk unit weight (KN/m ³)	16.25	0.66	15.59
	Dry unit weight (KN/m ³)	7.6	8.9	5.78
	Undrained shear strength (Kpa)	24	8	20
	Cohesion, C (KN/m ²)	25		19.5
	Angle of shearing resistance (Degree)	4	1	4
	Liquid limit (%)	70	16	62
	Plastic limit (%)	40	8	35
	Plasticity Index (%)	30	8	26
	Classification USCS	CH	CH	CH
	Coefficient of consolidation (m ² /Yr.)	1.79	0.66	1.46
	Coefficient of compressible (m ² /MN)	0.44	0.13	0.38
	Poisson's ratio	0.40	0.01	0.4
	Coefficient of earth pressure at rest, Ko	0.81	0.01	0.86

Table 2: Results of the Atterberg limit test

Location/ Borehole No.	Depth of sample (m)	Moisture content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity index (%)	Liquid index	Coefficient of Earth pressure at Rest, Ko	Casagrande classification
Amasoma 1	1.5	77.2	82.4	45.6	36.8	0.86	0.78	CH
	15.0	70.9	75.6	41.2	34.4	0.86	0.84	CH
	25.0	91.3	98.3	49.8	48.5	0.86	0.81	CH
2	2.0	76.5	81.2	45.2	36.0	0.87	0.81	CH
	4.0	39.8	46.5	23.5	23.0	0.71	0.84	CH
	8.0	70.9	78.6	45.8	32.8	0.77	0.74	CH
	17.0	71.4	79.0	48.9	30.1	0.75	0.86	CH
	20.0	62.0	72.3	42.1	30.2	0.66	0.83	CH
	22.0	64.8	74.5	44.2	30.3	0.68	0.84	CH
	25.0	90.2	98.2	49.5	48.7	0.84	0.79	CH

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Table3: Results of particle size distribution and drained direct shear test

Borehole No.	Depth of sample (m)	Moisture content (%)	Bulk Unit Wt KN/m ³	Angle of shearing Resistance (ϕ) Degree	Effective particle size D ₁₀ (mm)	D30 (mm)	Mean particle size D50	D60 (mm)	Coeff. of uniformity Cu=D ₆₀ /D ₁₀	Cc	USCS
1	4.0	12.3	18.4	25	0.035	0.082	0.096	0.102	2.914	1.883	SP
	31.0	11.8	19.8	28	0.100	0.200	0.302	0.352	3.520	1.136	SP
2	5.5	11.6	18.9	29	0.052	0.090	0.154	0.179	3.442	0.870	SP
	33.0	10.9	20.0	31	0.108	0.201	0.302	0.354	3.278	1.057	SP

Table 4: Results of the Undrained Triaxial compression tests

BH No.	Depth (m)	Moisture content (%)	Bulk Unit Wt KN/m ³	Dry Unit Wt. KN/m ³	Undrained Cohesion Cu KN/m ²	Angle of Shearing Resist. (ϕ) Degree	Shear Modul. MN/m ²	Poisson's Ratio
1	1.5	77.2	15.9	9.0	21	6	8.6	0.41
	3.0	40.5	17.5	12.5	26	5	9.7	0.40
	6.0	71.7	15.6	9.1	22	3	7.5	0.40
	15.0	70.9	15.2	8.9	19	4	7.6	0.42
	25.0	91.3	14.2	7.4	16	5	7.8	0.40
2	2.0	76.5	17.7	8.7	21	5	6.8	0.41
	4.0	39.8	15.1	12.7	24	4	11.2	0.40
	8.0	70.9	14.6	8.8	22	6	5.6	0.40
	22.0	64.8	16.6	10.1	18	6	8.4	0.40
	25.0	90.2	14.1	7.4	19	4	5.2	0.40

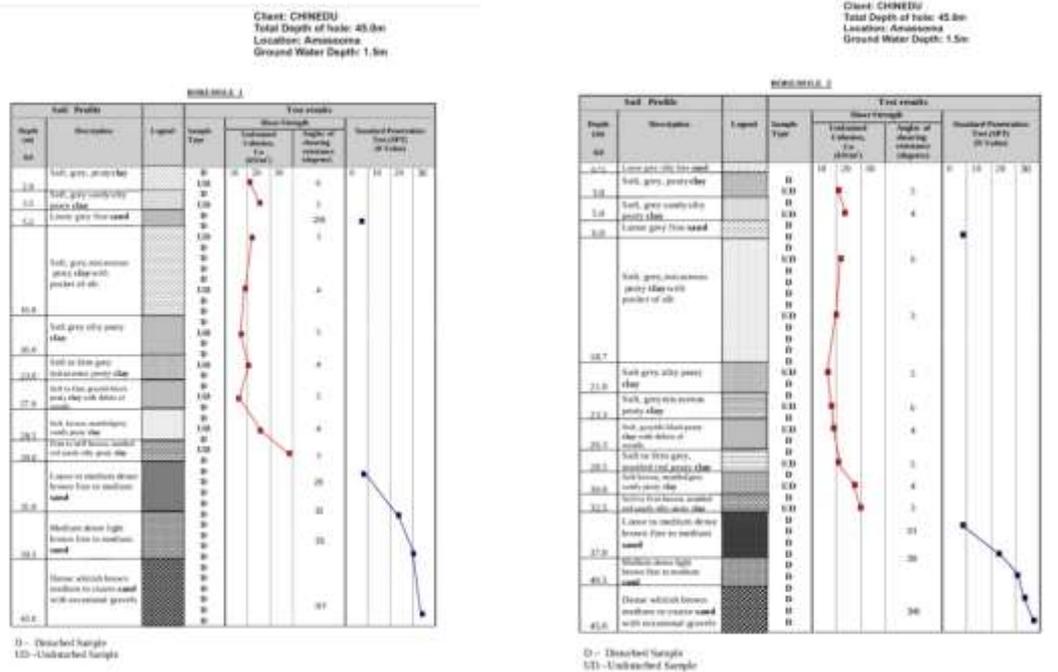
Medium dense sand: The sand is fine to medium grained, poorly graded, medium dense and greyish to brown in colour. The layers are almost of uniform gradation. The ranges of variations in relevant engineering parameters of the sand are shown in table 5.

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Table5: Characteristics values for sand samples

Soil type	Soil Parameters	Min.	Max.	Mean
Sand	Moisture content (%)	9.2	12.3	10.75
	Bulk unit weight (KN/ m ³)	18.4	20.0	19.2
	Effective unit weight (KN/ m ³)	8.31	9.09	8.7
	Poisson's ratio	0.40	0.43	0.42
	Angle of shearing resistance (Degree)	25	31	28
	Effective particle size, D ₁₀ mm	0.035	0.108	0.072
	Effective particle size, D ₃₀ mm	0.082	0.201	0.092
	Mean particle size, D ₅₀ mm	0.096	0.302	0.142
	Effective particle size, D ₆₀ mm	0.102	0.354	0.228
	Coefficient of uniformity Cu= D ₆₀ /D ₁₀	2.914	3.442	3.178
	Coefficient of curvature Cc = (D ₃₀) ² / D ₆₀ .D ₁₀	1.136	1.883	1.510
	Classification USCS	SP	SP	SP

The most notable characteristics of the soils is their very high natural moisture content, ranging from 46.5 % to 98.3%. These values indicate that the soils are nearly saturated, which is consistent with the high groundwater table and poor drainage conditions prevalent in the area. High moisture content generally reduces soil strength and increases compressibility. Atterberg limit results reveal that the liquid limit ranges from 46.5- 98.3%, the plastic limit ranges from 26.7- 49.8% while the plasticity index ranges from 23.0- 48.5%, indicating that the clays are highly plastic (CH) on the bases of unified soil classification system (USCS). The particle size distribution reveals that the cohesionless soil samples are predominantly fine to medium, medium dense poorly graded sand (SP). The cohesive soils are highly organic clays and peats that are very soft and very highly compressible as the values of coefficient of volume compressibility (M_v) vary between 0.23 and 0.833m²/MN, which can lead to significant long-term settlement under sustained loads.



Borehole log for BH1

Borehole log for B

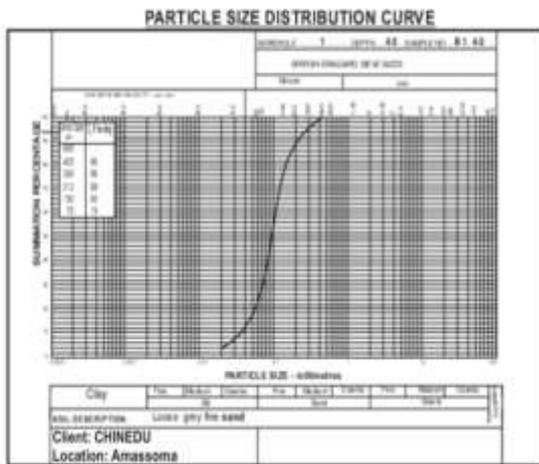


Fig.3: Particle size distribution curve BH1 @ 4.0m

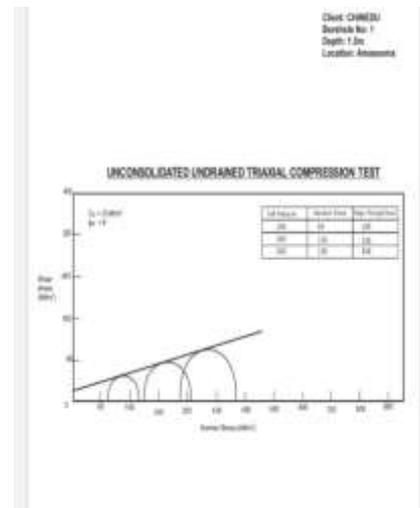


Fig.4: Mohr circle for BH1 @ 1.5m

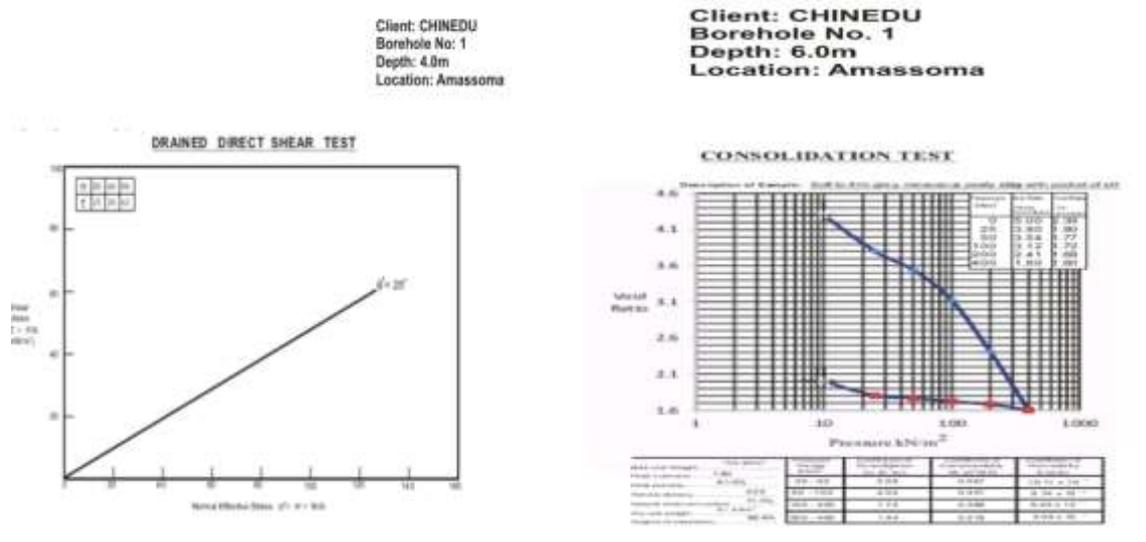


Fig. 5: Direct shear test for BH1 @ 4.0m Fig. 6 Consolidation test for BH1 @ 6.0m

Conclusion: The engineering geological investigation conducted in Amasoma has provided valuable insight into the geotechnical characteristics of the near-surface soils and their implications for shallow foundation construction within the Niger Delta environment. The suitability of soil as foundation material depends on a combination of the above properties. Ideally, a foundation material should have high shear strength, low compressibility, low plasticity, moderate permeability, and sufficient density to ensure stability and longevity of the structure. Foundations in areas with unfavourable soil properties (such as expansive clays or loose sands) may require specialized foundation designs, like deep foundations or soil stabilization techniques, to ensure structural integrity. Finally, the raft foundation is the most suitable as it provides support in highly compressible, low strength foundation materials.

Declaration of Conflict of Interest: There is no conflict of interest.

Data Availability: Data are available upon request.

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