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Evaluation of Shallow Foundation Soils around Lagos Using Results from Cone Penetration Test

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----------ABSTRACT----------

The penetration properties of some soils around Lagos were evaluated using the 2.5 Tons Dutch Cone Penetrometer. The aim of the test is to provide data that will be used alongside other field and laboratory test results to characterize soil properties around areas marked for development and also provide data for foundation design. The scope of the assignment was limited to investigating the suitability of the areas for erecting shallow building foundations. Results obtained from the site were found to be favourable for location of shallow foundations as the Penetration resistance obtained on all the four locations ranged between 60 KN/m^2 to 300 KN/m^{2}for depthrange of1 to 3 meters. It was observed that the tip resistance for places where Sand were encountered were considerably higher than areas where clay and other soil types were encountered. Results of 16 Cone Penetration Test points are presented.

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I. INTRODUCTION

Several cases of building collapse have occurred around Nigeria within the last few years. Though several factors such as poor construction methods, use of substandard material, poor foundation etc., can result to collapse of buildings, the need to ascertain that foundations for buildings are adequately designed cannot be overemphasized. Moreover, Oyedele and Olorode (2010) reported that several organizations and individuals have been engaging in infrastructural developments in recent times without engaging the services of relevant professionals so as to maximize profits. Where there is inadequate or insufficient subsoil characterization and soil strength determination, a potential related failure or structural dilapidations may occur (Ibrahim, 2013). Cone Penetration Test (CPT) a method used to determine the geotechnical properties of soils and also delineate soil stratigraphy is one of the most popular methods for assessing the suitability of soils as foundation material. Relative to other soil engineering methods for exploring site stratigraphy and obtaining data for preliminary design, CPT has the advantage of providing reliable data for foundation design speedily. However, the disadvantage of this test lies in the fact that samples are not recovered during the test for visual sighting and laboratory inspection, coupled with the fact that there may be cases in which depth of probe is limited.CPT can be used to evaluate competence of subsurface layers, determine optimum depth to competent layers and provide preliminary recommendations for foundation design; the CPT is particularly useful in investigation of coarse soils such as Sand. CPT has also proven useful for checking the adequacy and competence of excavating undesirable materials and replacing with suitable materials (Schmertmann, 1977). Though CPT results are significantly affected by grain size distribution, cementing lateral stresses, depth of overburden, permeability, tip shape, pore water pressure and thin layer effects, it still provides an indicator of the relative density of sand (Schmertmann, 1977). CPT can also be used to estimate the extent of consolidation in clay and is widely accepted as one of the most effective methods for liquefaction assessment. By applying the CPT, soil data can be obtained for every 20mm of depth and this ensures greater reliability of soil data. However, despite the numerous advantages of the Cone Penetration Test, soil classification based on only interpreting results of the test is still a challenge in the geotechnical industry (Libric, Kovacevic and Kacunic, 2017). Two kinds of penetration tests recognized in the Civil Engineering industry are the Dynamic Penetration and Static Penetration (Anon, 1975 and 1981). The Dynamic Penetration test also referred to as Standard Penetration Test (SPT) involves driving a 51mm external diameter split tube sampler connected to drilling rods in the ground by series of hammer blows and tests conducted at intervals during the course of boring,while providing disturbed samples for identification purpose. The Static Penetration on the other hand involves driving a conical point into the ground by applying a steady pressure on top of the rods. Both tests produce a complex failure surface within the soils.The Static Penetration Test method was applied in the case of this study.

II. LITERATURE REVIEW

The primary purpose of detailed geological and geo-engineering subsurface investigation is to provide data for design earthworks and foundation for structures and to execute work repairs necessitated by changes in subsurface environment (Oyeyemi and Olofinmade, 2016). The Cone Penetration Test (CPT) is an especially useful way to evaluate soil profiles as it is able to determine fine changes in a soil layers stratigraphy. In geotechnical investigation, Standard Penetration Test (SPT) provides data regarding the soils resistance to penetration in relation to the soil strength in terms of number of blows (N-Values). In evaluation of pavement properties, the California Bearing Ratio of Subgrade (CBR) which plays a major role in pavement design can be predicted using other support tests such as the Dynamic Cone Penetrometer Index (Deepika and Chakravarthi, 2012). They (Deepika and Chakravarthi) also explained that the Dynamic Cone Penetrometer (DCP) Index is influenced by various soil and material factorsnotable among the factors include subgrade types, vertical confinement effect and side friction effect of subgrade.For fine grained soil DCP index is significantly affected by the moisture content, AASHTO soil classification, dry density and coefficient of uniformity. In granular soils, Aggregate size affectsthe index.Adamu, Ezeribe and Oyedeji (2010) in a study of the Engineering Properties of Soils around Aba in South Eastern part of Nigeria recommended that for design of strip/square footing 1.5 metres wide by 1.5 meters deep, bearing capacity of 25kN/m^2 determined from cone penetration test is suitable for use. Oyeyemi and Olofinnade (2016) carried out a study to characterize near surface soils around Lakowe in Lekki, Epe, Lagos-Nigeria using geotechnical resistivity topography supported by cone penetrometer test and reported an average cone penetrationof 110kg/cm^2 which suggests soil at the study area was suitable for foundation use. In a similar study, Ademola and Adebayo, (2015) confirmed there is a strong corroboration between results obtain from 2D resistivity measurements and previous works done on same location using the Cone Penetrometer. Coker (2015) in a study to characterize soils on a construction site in Lagos using 1-D and 2-D resistivity Probing technique revealed that there is a strong agreement between the geophysical method and geotechnical method applying CPT.Oyedele, F.K and Okoh, C (2011) reported that

The application of geophysical and geotechnical methods in subsoil investigation at Magodo phase 11 Lagos, Nigeria has revealed the presence of five subsurface geo-electric layers. This consists of top soil, sandy clay, sand, clay and sand. The sand range is thickness from 14.33 to 37.3m while the depth to sand body varies from 3.335 to over 70m. The clay layer ranges in depth from 22.4 to 43.89m while its thickness varies from 27.64 to 55.89m. The 2-D resistivity profiles revealed the lateral variation of the subsurface litho-logy with depth. Also the Cone Penetrometer Test (CPT) shows competent value for penetrative resistance at 14 to over 18m. The study shows that shallow foundation is feasible in some part of the study area. The results of the two methods correlate well with each other.

Mohammed and Khamehehiyan, (2004) reported thatfor Dynamic cone penetration test, there is a very good correlation between Penetration Index and engineering properties obtained for each type of soil tested, the coefficient of determination R^2 ranges between 0.96 to 0.99 and the standard error of estimation is relatively low. They also concluded that the Dynamic Cone Penetration Index (DCPI) can be used to determine average CBR in a relationship expressed as log (CBR) =0.44-0.296 log (DCPI). However, it is worthy of note here that Begemann (1965) proved that generally coarse grained soils have a higher tip resistance q_c and sleeve friction f_s compared to fine grained soils.

Geology of Study Area

The study areas are parts of Lagos State in the South Western part of Nigeria. The geology of Lagos is dominated by crystalline and sedimentary rocks both occurring approximately in equal proportion (Ayolabi et al, 2012). Lagos and its environs are an integral part of Dahomey Basin which is in the Eastern part of Sedimentary Basin that extends from Volta Delta State in Ghana to Okitipupa ridge in Nigeria. Lagos belongs to the coastal plain sand formation which is made up of lose sediment ranging from silt, clay and fine to coarse grained sands. The test sites are located within old beach ridges, which run approximately parallel to the Atlantic Coast; though hardly over 25km in width, stretches westwards to Benin Republic. These ridges are recent deposits of coarse sands, shelly and sometimes alternating with variable thickness of organic clays and carbonized vegetable matter (peat). The sediments were clearly deposited under littoral and lagoon conditions and reflect the continuous shifting lagoon and sea each patterns and the varying sediments conditions within the environment.

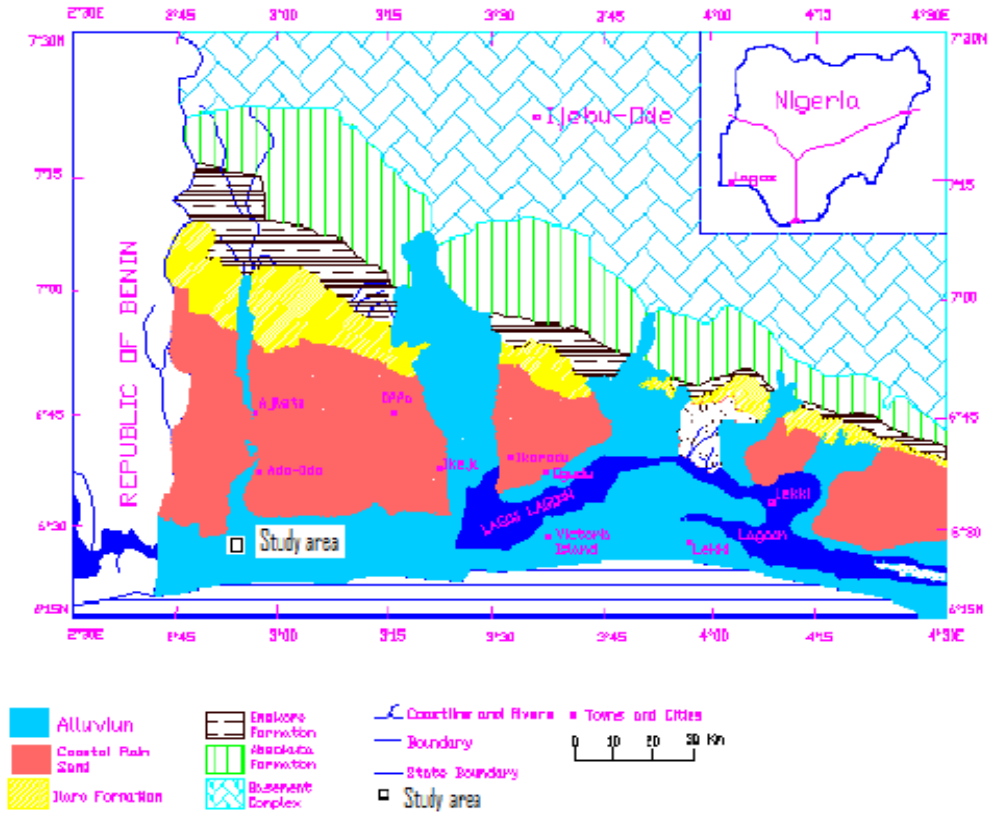


Figure 1 Lagos Geological Map, Adegoke 1969

III. METHODOLOGY

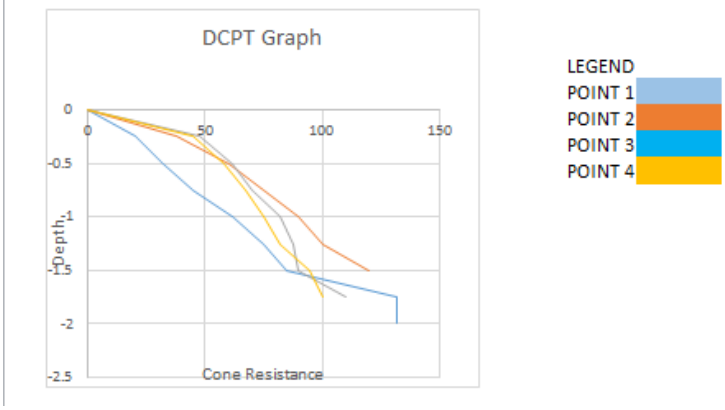
The Static Cone Penetration Test (CPT) using a 2.5 Tons capacity machine was engaged for the purpose of this investigation. The test involves driving a 60 degrees cone shaped point having a base area of 1000mm^2 into the ground at a constant rate of 20 mm per seconds whilst the resistance to penetration is measured. The method issuitable for investigation of Soft Clays, Silts and Sands (Sanglerat, 1972). Four different sites were investigated and the penetration resistance was checked at 4 points on each site. A linear graph of cone resistance against depth of penetration was plotted so as to see the behaviour of the soil at various depths down to the point of refusal. Test was carried out as specified in ASTM Standard D 3441, standardised in 1986.

IV. RESULTS

1. For site 1 (VGC area, Ajah Lagos) Penetration resistances of 132, 120, 90 and 100 were observed for 4 different points with depth at refusal ranging from 1.5 to 2.0m
2. For Site 2 (BogijiLekki, Lagos) Penetration resistances of 80, 75, 52 and 70 were obtained at 4 different points with depth at refusal ranging between 1.5 to 2.0m
3. For site 3 (Okoko 1, Lagos) Penetration resistances of 120, 135, 140 and 165 were recorded with depth of refusal ranging from 1.25 to 1.5m
4. For site 4 (Okoko 2, Lagos) Penetration resistancesof 140, 130, 125 and 135 were observed at depths of between 2.25 to 2.75m

DCPT Test Results VGC Site Ajah, Lagos

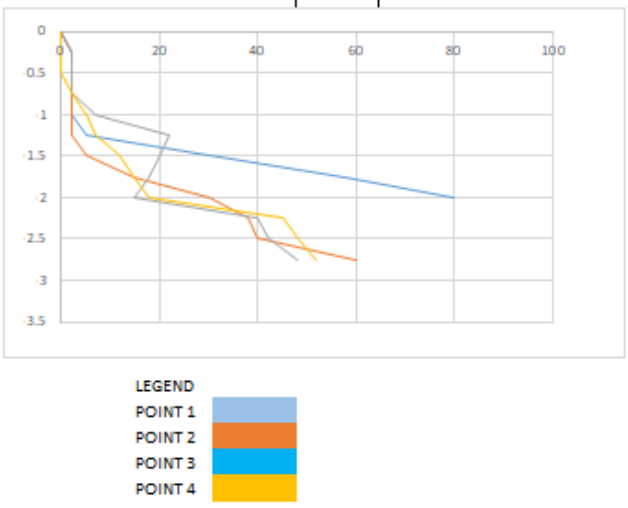
Point 1		Point 2		Point 3		Point 4	
qc	d	qc	d	qc	d	qc	d
0	0	0	0	0	0	0	0
20	-0.25	38	-0.25	48	-0.25	45	-0.25
32	-0.5	60	-0.5	62	-0.5	58	-0.5
45	-0.75	75	-0.75	70	-0.75	67	-0.75
62	-1	90	-1	82	-1	75	-1
75	-1.25	100	-1.25	88	-1.25	82	-1.25
85	-1.5	120	-1.5	90	-1.5	95	-1.5
132	-1.75		-1.75	110	-1.75	100	-1.75
132	-2		-2		-2		-2



SITE 1

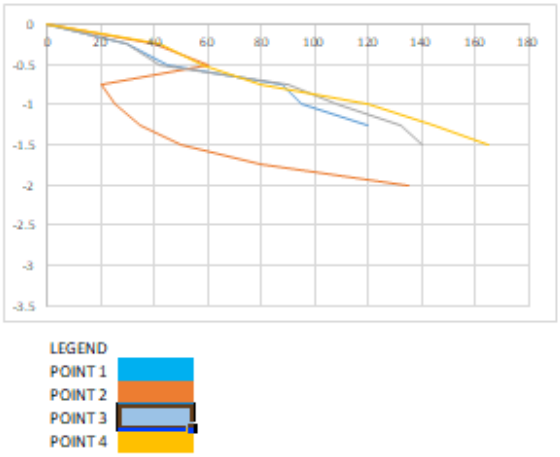
DCPT Results Bogije Site

P1		P2		P3		P4	
qc	d	qc	d	qc	d	qc	d
0	0	0	0	0	0	0	0
2	-0.25	2	-0.25	2	-0.25	0	-0.25
2	-0.5	2	-0.5	2	-0.5	0	-0.5
2	-0.75	2	-0.75	2	-0.75	2	-0.75
2	-1	2	-1	7	-1	5	-1
5	-1.25	2	-1.25	22	-1.25	7	-1.25
30	-1.5	5	-1.5	20	-1.5	12	-1.5
58	-1.75	15	-1.75	18	-1.75	15	-1.75
80	-2	30	-2	15	-2	18	-2
	-2.25	38	-2.25	40	-2.25	45	-2.25
	-2.5	40	-2.5	42	-2.5	48	-2.5
	-2.75	60	-2.75	48	-2.75	52	-2.75
	-3	75	-3	52	-3	70	-3



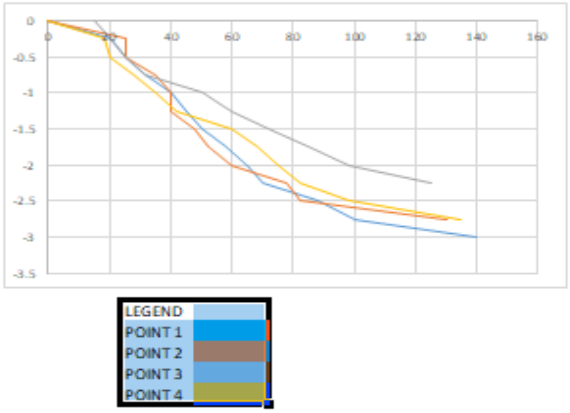
SITE 2

DCPT Results Okoko Site							
P1		P2		P3		P4	
qc	d	qc	d	qc	d		
0	0	0	0	0	0	0	0
30	-0.25	40	-0.25	30	-0.25	42	-0.25
45	-0.5	60	-0.5	42	-0.5	58	-0.5
88	-0.75	20	-0.75	90	-0.75	80	-0.75
95	-1	25	-1	108	-1	120	-1
120	-1.25	35	-1.25	132	-1.25	145	-1.25
	-1.5	50	-1.5	140	-1.5	165	-1.5
	-1.75	80	-1.75		-1.75		-1.75
	-2	135	-2		-2		-2
	-2.25		-2.25		-2.25		-2.25
	-2.5		-2.5		-2.5		-2.5
	-2.75		-2.75		-2.75		-2.75
	-3				-3		-3



SITE 3

DCPT Results Okoko Site 2							
P1		P2		P3		P4	
qc	d	qc	d	qc	d	qc	d
0	0	0	0	15	0	0	0
20	-0.25	25	-0.25	20	-0.25	18	-0.25
25	-0.5	25	-0.5	25	-0.5	20	-0.5
32	-0.75	35	-0.75	32	-0.75	28	-0.75
40	-1	40	-1	50	-1	35	-1
45	-1.25	40	-1.25	60	-1.25	42	-1.25
50	-1.5	48	-1.5	72	-1.5	60	-1.5
58	-1.75	52	-1.75	85	-1.75	68	-1.75
65	-2	60	-2	98	-2	75	-2
70	-2.25	78	-2.25	125	-2.25	82	-2.25
88	-2.5	82	-2.5		-2.5	98	-2.5
100	-2.75	130	-2.75		-2.75	135	-2.75
140	-3				-3		-3



SITE 4

V. CONCLUSION

Four sites were investigated around Lagos for the purpose of assessing if shallow foundations for bungalow buildings can perform satisfactorily on the sites. 2.5 Tons Cone Penetrometer was used for the preliminary assessment prior to recovery of samples for a detailed laboratory test to enable proper Characterization of the sites. Penetration resistance of the soils investigated were found to range from 100 KN/m^2 to 140 KN/m^2atrefusal depths ranging from 1.25m to 3.0m. The test result presupposes that the sites are suitable for location of the proposed shallow foundations. Soils encountered during the investigation were sandy in nature. The CPT is a cheap and efficient geotechnical investigation method for assessing the suitability of foundation soils; however for complete characterization of soils on a site, data obtained from CPT should be used in conjunction with other geotechnical and geophysical tests.

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