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Research Article

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Pile Load Test: A Case Study of Port Harcourt Metropolis

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Abstract The Study was carried out to ascertain the acceptability of an adopted specified working load of piles for substructure design . Static load test was carried out on a single pile of 450mm by 21m depth with pile design load of 360KN installed by Direct Mud Circulation. The Study reveals a non-defective pile with good founding depths based on obtained elastic rebound values of 90.4% . Settlement Curve also reveals embedded depth in a medium dense sandy layer. Observed Total Settlement value of less than 10% the Pile diameter on a Proof Load of 760KN meets the settlement criterion adopted for the study. Though the pile was not loaded to failure, calculated factor of Safety exceeds 2.0, indicative of an acceptable standard.

Keywords Pile, Niger Delta, Port Harcourt, Rivers State, Static Load Test, Pile Load Test

Introduction

With the increasing urbanization within the study area (Port Harcourt, Rivers State) and the limited stable land, the use of Pile foundation has become prevalent in sub-soil structures. Akpokodje [1], stated the general swampiness of the terrain as a factor that constitutes serious constraints to civil engineering construction within the region. Also, Abam [2] stated the challenges in physical development as a reflection of the poor soil conditions (low Bearing , high compressibility etc) of the Niger Delta region.

Pile foundation is a Deep Foundation that transmits foundation loads through soil strata of low bearing capacity to deeper soil or rock strata with higher bearing capacity [3].

Though, it is suitable form of foundation for greater loads or weak soils, ascertaining the estimated load capacity (obtained from soil Mechanics) of the piles via load tests is a necessity as stated in the works of Muthukkumaran *et al* [4]. Piles can be tested to confirm its vertical , lateral or uplift capacities. Static load test is the most basic test and it involves the application of vertical load directly to the pile head. It is considered as the benchmark for pile performance [5]. The necessity of pile load test is also prompted by the facts of buildings collapsed even on piles. The shape of the load-settlement curve of a pile can yield more information than the directly obtained raw data related to load-settlement behaviour. [6] Though, Pile load testing can represent reasonable results, such tests are expensive, time-consuming, and the costs are often difficult to justify for ordinary or small projects [7]. The tests gives the Geo-professional information needed to allow the use of a more “rational” foundation design. The test is a proof of acceptability of proposed design load [8]. Pile load test also confirms the pile - soil systems used in the proposed design load.

This test was carried out on a Predetermined Bored Pile of 450mm and a depth of 21m (Non Displacement pile) with a proposed Design Load of 360KN (Safe or specified working load). The Piles installation was based on the Direct Mud Circulation method. The objective of the load test on the pile was to verify the proposed assumption for the pile capacity based on soil mechanics theory and also determine the settlement at safe working load, thereby leading to cost effective designs.

Geology

The study area is located within G.R.A Phase 1, Port Harcourt, with Geographical Location, N 04^0 48'30.042" E 06^0 59' 37.23". Geologically, the site is underlain by the Coastal Plain sands, which in these areas are overlain by Alluvial Pleistocenic soft-firm silty clay sediments belonging to the Dry flat land and plain of the geomorphic units of the Niger Delta. The Niger Delta consist of three basic stratigraphic units, the Benin, Agbada, and the Akata Formations [9]. Generally geology of the areas essentially reflects the influence of movements of rivers, in the Niger delta and their search for lines of flow to the sea with consequent deposition of transported sediments. In broad terms, the areas may be considered flat.

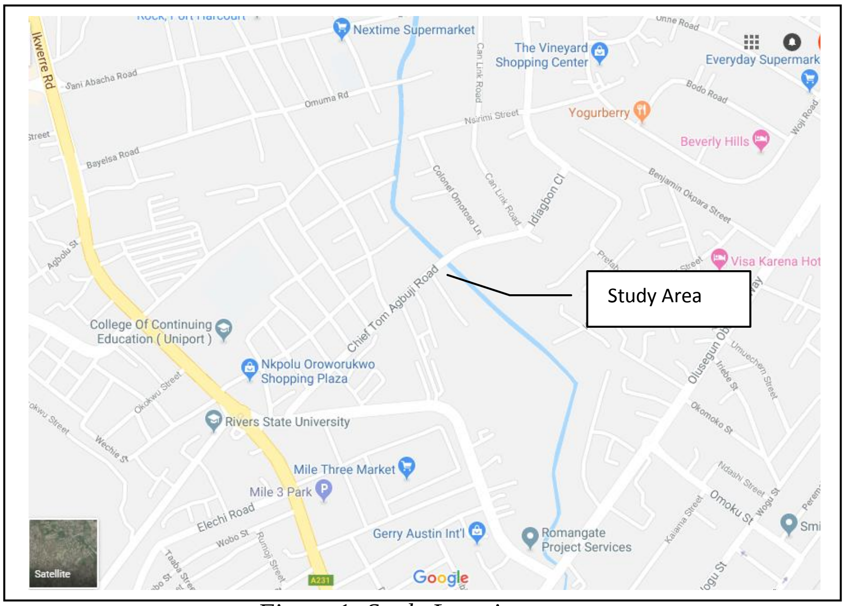

Figure 1: Study Location

Materials and Method

The test was conducted according to BS 8004, 1986, section 7.5 for maintained load test (compression). For conducting the pile load test, the reaction load (Kentledge) was placed on a predetermined pile, the load was then applied by means of a hydraulic jack, with an increment of 0 to 72 tons. At each load increment, the settlement was recorded after 0,4, 10,40,60, to 720 minutes. Each load was maintained until the rate of settlement was not greater than 0.25mm per hour . The Test method involves two different Cycles; Cycle 1 was tested to 100% of the Design Load, while Cycle 2 was tested to 200% of the design Load.

Failure criterion

The pile can be regarded as not functional, if the gross settlement of the pile after the test is greater than 10% of the Pile diameter.

Results and Discussion

Soil Properties

Soil Stratigraphy

A typical soil profile characterizing the site is described below.

Table 1: Litholgy, bh1

Layers	Depth(m)	Lithology	Cu (KN/m^2)	Phi (^{o})
1	0-6	Clay , soft Layer	19	
2	6-7	Clay, Sandy Soft layer		
3	7-13	Sand , loosed, fine		28
4	13-14	Clay, Sandy Soft layer		
5	14-18	Sand, loosed, fine		28
6	18-30	Sand , Medium Densed		31

Load Test

Table 2 -Point 1 1st cycle

	Time (mins)	Load (ton)	Settlement Rd 1(mm)	Settlement Rd 2(mm)	Average settlement, mm	Cul. Average (mm)
Loading 25%	0	0	10.44	10.37		
	0	9	10.44	10.37		
	4	9	10.445	10.37		
	10	9	10.448	10.37		
	20	9	10.448	10.37		
	30	9	10.448	10.37	0.004	0.004
Loading 50%	0	18	10.448	10.37		
	4	18	10.45	10.37		
	10	18	10.45	10.38		
	20	18	10.45	10.39		
	30	30	10.45	10.4	0.016	0.02
Loading 75%	0	27	10.45	10.4		
	4	27	10.45	10.4		
	10	27	10.45	10.4		
	20	27	10.45	10.4		
	30	30	10.45	10.4	0	0.02
Loading 100%	0	36	10.45	10.4		
	30	36	10.47	10.40		
	60	36	10.50	10.51		
	90	36	10.5	10.52		
	120	36	10.5	10.52		
	150	36	10.53	10.52		
	180	36	10.55	10.522		
	210	36	10.55	10.522		
	240	36	10.55	10.522		
	270	36	10.55	10.522		
	300	36	10.55	10.522		
	330	36	10.55	10.522		
	360	36	10.55	10.554	0.127	0.147
Unloading 75%	0	27	10.55	10.554		
	4	27	10.55	10.554		
	10	27	10.55	10.554		
	15	27	10.55	10.554	0	0.147
Unloading 50	0	18	10.55	10.554		
	4	18	10.55	10.554		
	10	18	10.55	10.554		
	30	18	10.55	10.554	0	0.147
Unloading 25%	0	9	10.55	10.554		
	4	9	10.55	10.554		
	10	9	10.55	10.554		
	30	9	10.55	10.554	0	0.147
Unloading 0%	0	0	10.55	10.554		
	4	0	10.53	10.54		
	15	0	10.522	10.535		
	24 hrs	0	10.52	10.53	0.027	0.12

Table 3: Point 1 2nd cycle

	Time (mins)	Load (ton)	Settlement Rd 1(mm)	Settlement Rd 2(mm)	Average settlement, mm	Cul. average(mm)
Loading 100%	0	0	10.22	10.64		
	0	36	10.22	10.64		
	4		10.282	10.65		
	10		10.29	10.65		
	20		10.29	10.65		
	30		10.29	10 .65	0.04	0.04
Loading 125%	0	45	10.29	10.65		
	4		10.36	10.66		
	10		10.41	10.66		
	20		10.41	10.70		
	30		10.41	10.702	0.086	0.126
Loading 150%	0	54	10.41	10.702		
	4		10.77	10.999		
	10		10.80	11.11		
	20		10.86	11.15		
	30		10.872	11.19	0.475	0.601
Loading 200%	0	72	10.872	11.19		
	60		11.87	12.72		
	120		11.93	12.28		
	180		11.975	12.36		
	240		12.03	12.368		
	300		12.05	12.425		
	360		12.084	12.45		
	420		12.1	12.47		
	480		12.1	12.49		
	540		12.14	12.49		
	600		12.15	12.49		
	660		12.15	12.49		
	720		12.15	12.49	1.289	1.89
Unloading 150%	0	54	12.15	12.49		
	30	54	12.1	12.48	0.03	1.86
Unloading 125%	0	45	12.1	12.48		
	30	45	12.05	12.47	0.03	1.83
Unloading 100%	0	36	12.05	12.47		
	30	36	12.02	12.46	0.02	1.81
Unloading 75%	0	27	12.02	12.46		
	30	27	11.97	12.4	0.055	1.755
Unloading 50%	0	18	11.97	12.4		
	30	18	11.95	12.38	0.02	1.735
Unloading 0%	0	0	11.95	12.38		
	24 hrs	0	11.93	12.35	0.025	1.71

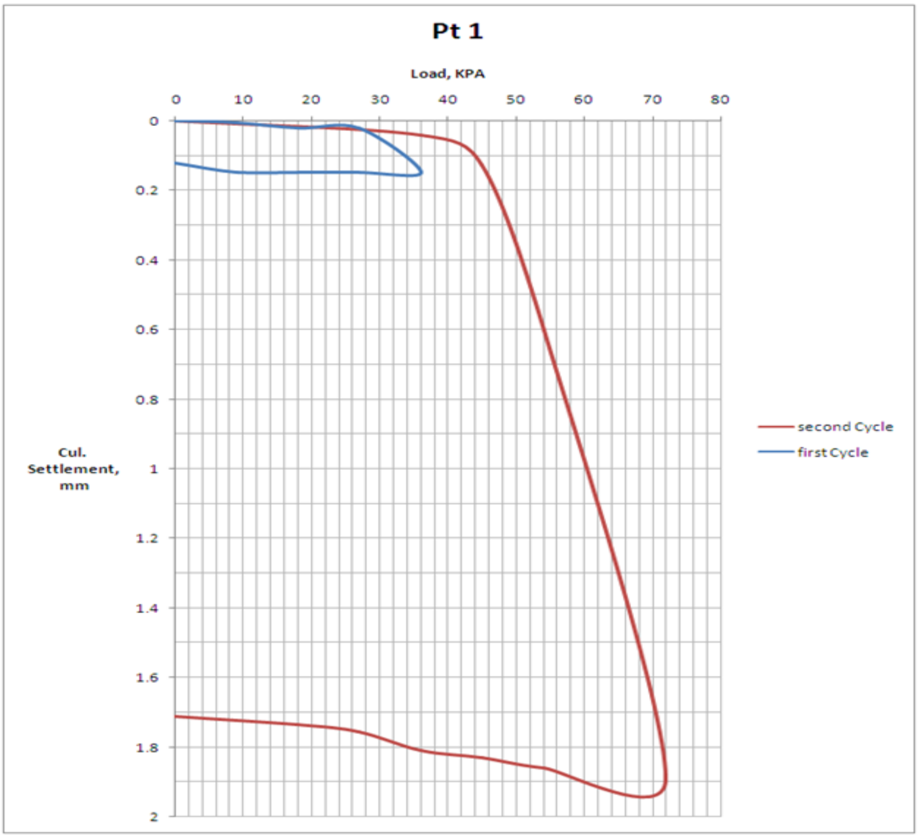

Figure 2: Load – Cumulative Settlement Curve for Point 1

Table 4: 1st cycle (Loading to Pile Design Load of 360KN)

Load (ton)	Cummulative Settlement(mm)
0	0
9	0.004
18	0.02
27	0.02
36	0.147
27	0.147
18	0.147
9	0.147
0	0.12

Table 5: 2nd cycle (Loading to Pile Test Load of 720KN)

Load (Ton)	Cummulative Settlement(mm)
0	0
36	0.004
45	0.126
54	0.601
72	1.89
54	1.86
45	1.83
36	1.81
27	1.755
18	1.735
0	1.71

Table 6: Deformation Characteristics for 1st Cycle

Test point (TP)	Diameter	Dept	Pile Design Load (KN)	Pile Test Load (KN)(ultimate)	Deformation Characteristics Cul. Settlement S_t (mm)
1	450mm	21m	360	720	1.89

Table 7: Deformation Characteristics for 2nd Cycle

Test point (TP)	Diameter	Dept	Pile Design Load (KN)	Max. Applied Load (KN)(ultimate)	Deformation Characteristics Cul. Settlement S_t (mm)
1	450mm	21m	360	720	1.89

With a suitability of two times the specified design load for the proof load as stated by Tomlinson [2] , the results shows that the nature of the load / settlement curve depicts a normal curve with medium dense sand inclination , exhibiting both frictional and end bearing resistance. The nature of the curve also reveals a non – defective pile shaft. Cumulative gross settlement with the proposed Pile Design load of **360KN**, indicates 1.47 mm. Pile Test Design load or proof load of **720KN**, indicates a gross settlement of 1.89 mm and a residual settlement of 1.71mm. High Elastic rebound of 90.4% shows good founding depth for the pile. The gross settlement value of the proof load is less than 10% of the Pile Diameter and a net settlement of less than 0.5 inch is implicative of a functional piles [10]. This implies that the observed settlement can be tolerated by the superstructure as indicated by the relevant standards without any impact on the safety and serviceability of the building. This also indicates that the proposed Design Load or specified working load of 360 KN is within acceptable limit for the pile foundation design. The study also confirms a high Safety of Factor that is greater than 2, based on specified working load adopted for the design, which signifies good value.

Conclusion

The test reveals that the proposed Pile design load or specified working load (360KN) of the pile with the following characteristics of 21m by 450mm meets the acceptable criteria; this implies that this design load of the pile can be adopted for the design of the sub-structure To ascertain the maximum Safe working load limit of the pile for optimal pile design, it is necessary to perform the load test to failure in order to obtained its ultimate bearing capacity and hence its actual allowable bearing capacity.

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