Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-761

Determination of soil bearing pressures using a modified Plate Load Tester in the Nigerian Niger Delta

Determination de la capacité de pression du sol en utilisant un testeur de charge modifié au Delta du Niger au Nigeria

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ABSTRACT
The determination of the bearing capacity of sub-soils using the conventional Plate Load Testing Techniques usually involves firmly grouted heavy reaction piles, H-beams, extremely heavy dead weights, slow-moving barges and tug-boats that are not only time - consuming but very expensive to employ. A Modified Plate Load Tester that comprises a 0.4064meter (16.00 inch) square base, a 0.2032meter (8.00 inch) diameter and 0.762m (2.50 feet) long cylindrical steel stem with a receptacle for load bearing at its top, two (2) 254mm-range dial gauges for settlement measurements, two (2) magnetic dial gauge holders, two (2) 1.22-meter long, 0.051-meter diameter steel rods driven 0.75 meter into the ground for dial gauge support and sixteen (16) equal weights of 160.00 kg each, has been devised. This technique has been successfully employed for the determination of the load bearing capacity of sub-soils for emplacement of 300.00 kPa INO ATM & INO LP Separators at an Oil Flow Station in the Freshwater Swamps of the Niger Delta at Ogboinbiri, Southern Ijaw Local Government Area of Bayelsa State of Nigeria. Field investigations indicated that the in-situ silty-clayey lateritic soils have undrained shear strength parameters of $\phi_u = 6^o – 10^o$ and undrained cohesion intercept (c_u) = 24.00 – 32.00 kPa, natural moisture content (w) = 36.5% ; and consistency limits of LL = 38.5%; PL = 11.6 – 13.8% . Using this modified Plate Load Tester, and testing at four (4) points situated within a designated area of 12m x 16m, the bearing capacity values of the soils which had earlier been improved upon by vibro-flotation, ranged from 431.82 to 462.57 kPa. These values were all above the designed bearing capacity of 300.00 kPa required for the placement of the Separators at the project site. This paper describes in detail the design and fabrication of the modified Plate Load Tester, its field applications using the procedures of ASTM D1194-72, field data acquisition, analysis and computations. The advantages and disadvantages of this Plate Load Testing technique over the conventional technique are also discussed.

RÉSUMÉ
La determination de la capacité de pression du sol en utilisant les techniques conventionelles de test normalement demande l'utilisation de lourds piliers, de lourds poids morts, des remorqueur-barges, tout cela est lent et couteux. Un testeur de charge modifié à été concu, il comprend une base de $0.4064m^2$, une colone de cylindrique enauer de 0.2032m de diametre et 0.762m de longeur, deux guage de 254mm pour la mesure de depot, deux (2) support magnetiques, deux (2) pilièrs d'acier de 0.75m, et seize (16) poids de 1600kg chacun. Cette technique a été utilisée avec success pour la determination a une station de pompage de petrole dans le delta du Niger a Ogboinbiri (Nigeria) pour installer des Separateurs de 300kPa INO ATM & INO LP. Les resultants montrent une le sol de laterite á une tension de $\phi = 6^o – 10^o$ et une cohesion C_u = 24.00 – 32.00 kPa. Le taux de moisisssure est de l'order, w = 36.5%, limites de consistence, LL = 38.5%; PL = 11.6 – 13.8% . En utilisant cette methode et testant quatre (4) points situeés dans un perimeter de 12m x 16m, la capacite de pression est de l'ordre de 431.82 á 462.57 kPa. Toutes ces values sont au dessus de la capacité exigée de 300.00 kPa requisé pour l'installation des Separateurs sur le site. Cette publication explique en detail la conception et la fabrication du testeur de Charge Modifie, son utilisatoion basée sur les procedures d'ASTM D1194-72, acquisition de données, L'analyse et les calculs. Les avantage et desavantages de cette technique comparee a la technique conventionnelle sont aussi discutes.

1 INTRODUCTION

The project site is located at the Ogboinbiri Oil Flow Station situated approximately on latitude 4^o 49' 40' North of the Equator and longitude 5^o 59' 30'' East of the Greenwich Meridian (Figure 1).

The general topography at the site is relatively flat-lying in a thickly vegetated freshwater swamp forest comprising tall trees with large canopies, tropical palm trees, raffia palm trees with other secondary vegetal growths characteristic of fresh water swamp zone of the Niger Delta sub-region of Nigeria.

The local geology of the project site is basically that of the Coastal Plains Sands and clays of the lower Quaternary (Pliocene-Pleistocene) and Alluvium of upper Quaternary (Recent sediments)

The subsurface conditions at the site comprise dense yellowish silty clay layer (CL) underlain by dark silty clayey sands (SC). These are further underlain by another cycle of dark silty clays and dark silty clayey sands before being underlain by well graded sands (SW) at depths of 15.00 meters and beyond.

Due to the maze of creeks, streams and rivulets that characterize this zone of the Niger Delta sub-region it is quite expensive to transport heavy reaction metal piles, H-beams and extremely heavy dead weights via large barges to project sites situated several tens of kilometers away from the State capitals and headquarters of companies. This was the major reason why the modified Plate Load Test equipment was devised.

2 DESIGN AND CONSTRUCTION OF THE PLATE LOAD TEST EQUIPMENT.

The modified Plate Load Test equipment comprises a 0.4064 meter (16.00 inch) square base, a 0.2032meter (8.00 inch) diameter and 0.762m (2.50 feet) long cylindrical steel stem of 1.50cm thickness with a load receptacle at its top. For measurements of settlements are two (2) 254mm range dial gauges fixed to two respective magnetic dial gauge holders attached to the stem of two (2) 1.22m long, 0.051m diameter steel rods, respectively, driven some 0.75m into the ground for stability and support of the dial gauges. Sixteen (16) equal weights of 160.00 kg, each measuring 62.00cm x 62.00cm x 5.00cm are used as loads. A set-up of the Plate Load Test equipment with loads mounted and dial gauges in place is shown in Figure 2.

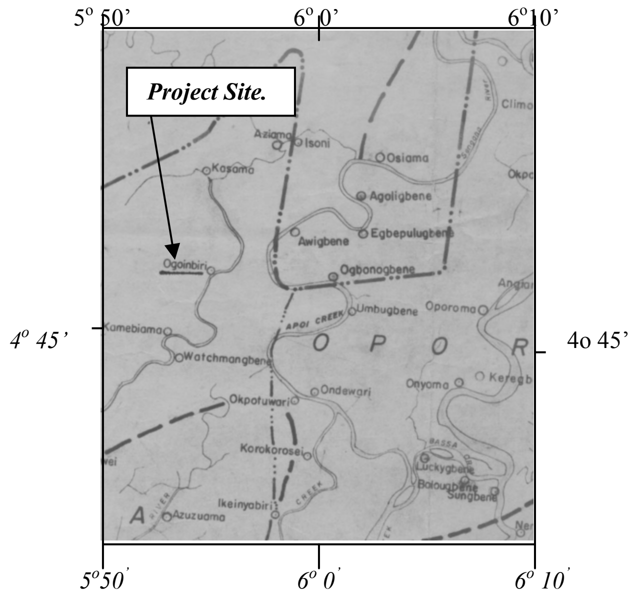
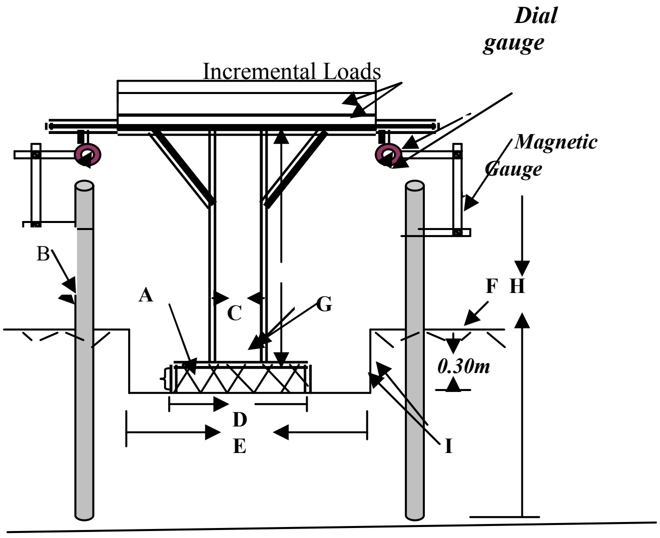


Figure 1: Location of Project site



A = Base of Plate Load Equipment B = Pipe Rod
C = 8" (2.44m) ϕ D = 16" (0.4064m)
E = 4 ft (1.219m) F = Ground surface
G = Thick-walled Steel casing H = 4 ft (1.219m).
I = Wall of excavation

Figure 2: Set-up of Modified Plate Load Test equipment

2.1 *Operation of the Plate Load Test Equipment*

For field operations, the modified Plate Load Tester is placed 0.3048m (1.00 foot) below ground level at the center of a 1.22m x 1.22m (4.00ft x 4.00ft) excavation. The loads are thereafter placed one after the other on top of the Plate Load Test equipment and measurements of settlements taken after each load emplacement.

3 FIELD INVESTIGATIONS AND RESULTS

A 300.00kPa capacity INO ATM and INO LP Separators were to be emplaced at the Ogboinbiri Oil Flow Station situated within the freshwater swamps of the Niger Delta sub-region of Nigeria. The position of the Separators is situated between an existing Separator and Oil manifolds and pipelines such as shown in Figures 3 and 4, respectively. Within the identified emplacement location were four (4) specified points at which the soil bearing capacities were determined (Figure 3).

Two dial gauges such as shown in Figure 5 were used to measure the settlements with elapsed time as each load increment was placed on top of the Plate Load equipment.

The settlements versus time readings for each load increment are tabulated and thereafter plotted on an x-y diagram such as shown in Figure 6.

After all the load increments have been emplaced at all the loading sites (ie. Sites #1,2, 3 & 4), the maximum settlements per loading were plotted against the respective maximum load increments (∑ Load) per site. (Figure 7).

2.2 *Determination of design pressure at each test point..*

Settlement considerations are by virtue of the inherent use of the consolidation theory equations limited to 25.4mm (1.00 inch) (Terzaghi and Peck, 1967; Peck, Hansen and Thornburn, 1974).

However, the ratio of the settlements of the foundation to that of the plate never exceeds 4.00 according to Scott (1980). Also,

Bjerrum and Eggestad (1963) have detected a tendency for higher settlement ratios to occur on more loosely packed soils, but this has not been confirmed in other cases. Though there does not seem to be any way of predicting foundation settlements from the results of small plate tests, the approach in this paper is an attempt to solve that problem, especially in improved soils such as in this case.

A Factor-of-Safety (FS) of 3.00 has been used to take care of unexpected settlement values that may likely be obtained at site.

The concept of Loading Factor ***(f)*** has been taken as the pro-por-tion of the maximum settlement ***(x)*** at a point to the maximum allowable of 25.40mm as obtains in the Terzaghi consolidation Theory, hence:

$$f = 25.40mm / x\ mm \qquad (1)$$

For instance, at project test site #1 with a maximum settlement of 3.33mm produced by a maximum load of 2972kg, over a plate footing area of 1651.61 cm^2, the allowable bearing pressure $[\,q_{(allow)}]$ is equal to:

$$[\{2972kg / 1651.61cm^2 (0.09807) (25.4 /3.33)\} / 3.0\,]\ MPa.$$

$$[\,q_{(allow)}] = 0.44868\ MPa = \underline{448.68\ kPa}.$$

Similarly, allowable bearing pressures are computed for the other three sites and test results tabulated as in Table 1 below. For stability of the Separator foundation, the net contact pressure q_{net} = 300kPa at the project site ≤ allowable reinforced soil pressure q_{allow}. = 448.28kPa.. Hence, the Separators could and were accordingly installed at the project site.

For the stability of a foundation to be assured it is necessary to re-assess the allowable bearing capacity such that $q_{net} \leq q_{(allow)}$. The average allowable bearing pressure from the four test sites gave $q_{(allow)}$ ~ 448.28kPa and this is less than the required q_{net} of 300.00kPa for the proposed separators, hence the proposed ***INO ATM and INO LP separators*** were successfully installed at the project site safely.

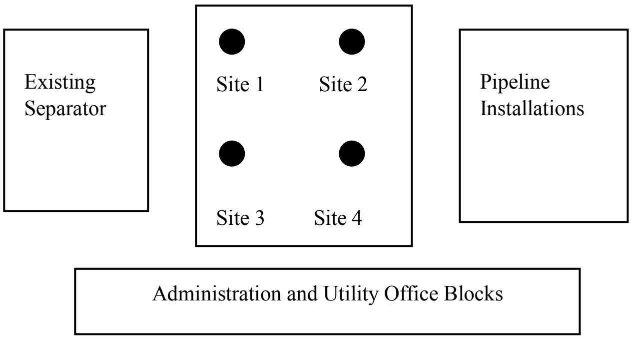


Figure 3: Diagrammatic representation of the Project site showing the locations of the Plate Loading points.

Figure 4: Set-up of the Plate Load Test equipment at the Ogboinbiri Flow station, Niger Delta sub-region, Nigeria.

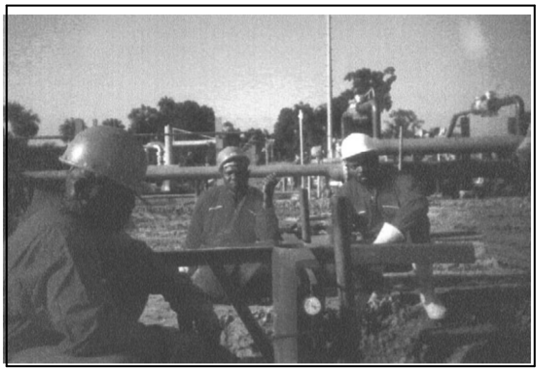


Figure 5: Set-up of the Plate Load equipment for settlement recording versus elapsed time at project site.

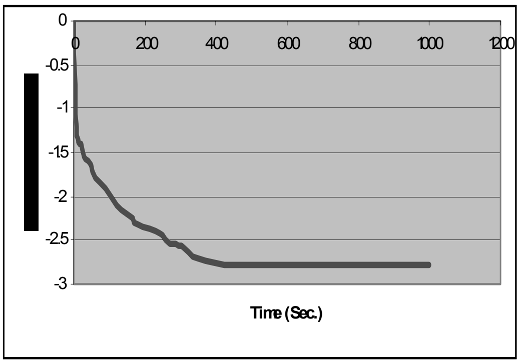


Figure 6: Plot of Settlement versus Time for Loading site #1.

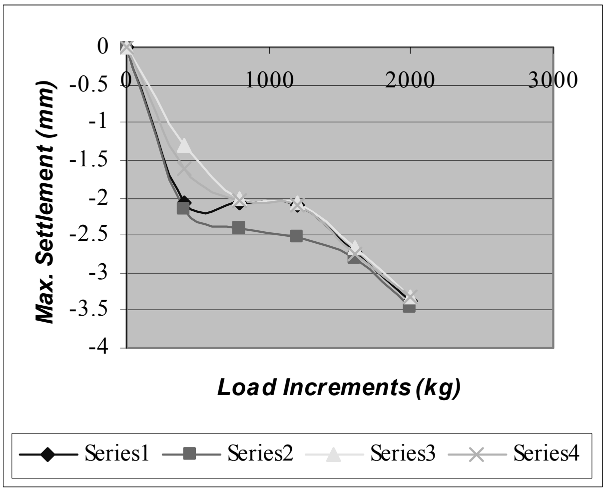


Figure 7: Plot of Total Load Versus Maximum Settlement for all sites tested.

Table 1: Summary of Field Results at the Test Sites.

Project Location	Test parameters	Test #1	Test#2	Test#3	Test#4
	Max. Settlement [mm]	3.33	3.46	3.32	3.23
	Loading Factor *(f)*	7.627	7.341	7.650	7.864
Ogboinbiri Flow Station, Bayelsa State.	q (ult.) [kPa]	176.47	176.47	176.47	176.47.
	Factor of Safety (F.S)	3.00	3.00	3.00	3.00
	.q (allow) [kPa]	448.68	431.82	450.03	462.57

4 ADVANTAGES AND DISADVANTAGES OF THE METHOD.

The advantages of this technique over conventional techniques include:

(i) Ease of transportation and applicability due to the reduced size and manageable dead weights,
(ii) Comparatively lower costs of production and carrying out of field tests,
(iii) Shorter duration of field application and
(iv) Ability to replicate field data on soils from similar eco logical zones.

5 SUMMARY AND CONCLUSSIONS.

On the basis of the field investigations carried out at the Ogbainbiri Flow Station, it was found that the bearing capacity of the treated freshwater swamp soils (using vibro-flotation technique) was *448.28 kPa* which was more than the required net soil pressure of *300.00kPa* needed for the installation of the Separators at the site. The Separators were therefore successfully installed at the project site.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the assistance of the staff of the clients – Cakasa Nigeria Limited – during the field experimentation of the modified Plate Load Tester at the project site and their permission to produce a manuscript of the report for publication. Staff of Teks Geotechnical Consultancy (Nigeria) Limited Port Harcourt, are also acknowledged for their various contributions both in the field and in the laboratories.

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