Base resistance of individual piles in pile group

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Abstract: - The base resistance of individual smooth model piles in the pile groups in sand under static loading is investigated experimentally in a pile soil test apparatus. The aim of the laboratory tests was to study and evaluate the behaviour of individual smooth model piles in the 5 and 9-pile groups under axial load with two different pile spacing in two different soil densities [medium dense and compacted] around the piles. The study show the effect of soil improvement around the piles in increasing the base resistance of individual smooth model piles in pile groups. The laboratory tests outlines the variation of the magnitude and the proportion of end bearing capacity of individual piles in different pile groups.

Key-Words: - base resistance- pile groups- bearing capacity- loading tests- central pile- laboratory tests

1 Introduction

Most theories consider the soil as a continuous elastic material. The theories suppose the angle of shear strength (Φ) and cohesion (c) to be constant, independent of the stresses and stress condition. The full shaft resistance is mobilised at very small displacements, whereas relatively large displacements are needed to mobilise the base resistance. The evaluation of base resistance is a bearing capacity problem, given by:

$Q_b = q_{ult} . A_{base}$

where, q_{ult} = ultimate bearing capacity of the base
A_{base} = area of the foundation base

Figure (1) (Kulhawy) shows that bearing capacity failure occurs as a shear failure in the soil supporting the foundation. Three principal failure modes can occur: general shear, local shear, and punching shear. The soil within the shear surface is assumed to behave as a rigid plastic medium and is idealised as three zones:

I - active Rankine zone
II - radial Prandtl zone
III- passive Rankine zone

The soil above the foundation base is modelled as an equivalent surcharge shown in figure (1). The rate of increasing the base resistance decreases with depth, primarily because of decreasing rigidity with depth, whereas for side resistance, the rate is a function of increasing overburden and decreasing Ko with depth (Kulhawy).

The base resistance of piles in sand is mainly considered from the viewpoint of the particle - crushing energy around the pile base, where the base resistance of piles in sand greatly depends on the particle-crushing property of the sand below the base to a depth of several times the pile diameter and the bulb-shaped particle crushing region of a dimension of two to three times the diameter of the piles develops around pile base.(Miura).

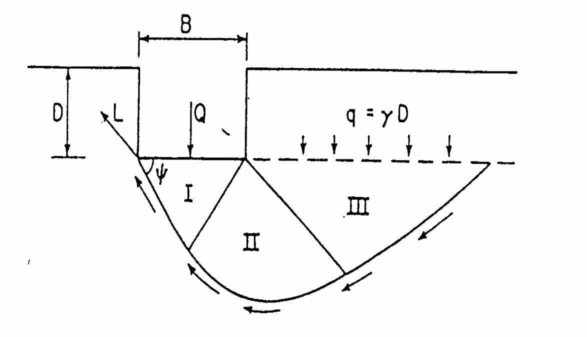


FIG.1. General description of bearing capacity [Kullhawy]

As shown by Vesic (1964) the failure mechanism below the base of a pile cannot be but a punching failure, even in very dense soils. The failure volume under a pile base is shown in figure (2). It is well known that the technology used has a major influence on the load bearing capacity and on the interaction between the soil and the pile

When taking into account the interaction between the pile and the surrounding soil and the influence of the interaction on the pile load bearing capacity, the investigation of changes caused by piles when driven into the soil is of great importance. Both the load bearing of the piles and the mechanism of load bearing should be taken into consideration according to the real conditions.

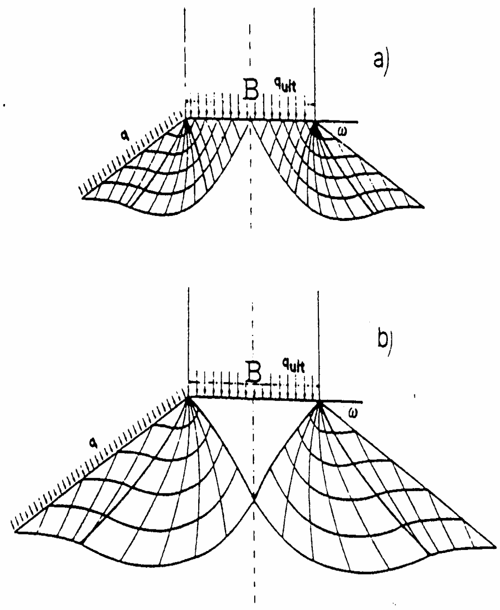


FIG. 2. Failure volume under pile point
a) smooth base : b) rough base
[Simone & Sapio]

It is well known that great emphasis has been laid in recent years, on the investigation of base resistance and shaft resistance, their ratio and the factors influencing this ratio.

The value of the base resistance and the depths to which it reaches depend significantly on the initial soil compactness..

2. Test Program

For determination of the bearing capacity of pile groups, carefully conducted and well documented laboratory tests are preferred, while field tests are very expensive, and a rather long time is required to obtain reliable final settlement values. Also, the bearing capacity results from just a few field loading tests are insufficient, since soil conditions vary and the scatter in the bearing value is high.

The aim of the laboratory was to study the behaviour and base resistance of individual smooth model piles in the group under load with two different pile spacing and soil densities around the piles. The test apparatus described for studying the behaviour of 5 and 9-pile groups of smooth model piles erected in a tank of dry sand proved to be a useful tool in studying point resistance behaviour. It offers certain features that can be advantageous in analysing the pile-soil interaction.The used coarse well graded homogenous sand was in a dry state with uniformity coefficient of C_U=2.8.The physical properties of the sand are shown in the Table.1.

Table.1. Physical Properties of Sand

Condition of sand	Dry density [g/cm^3]	Void ratio e	Internal friction angle Φ	Porosity n
medium dense dry sand [around piles]	1.62	0.65	36	0.40
dense dry sand [around piles]	1.72	0.56	41	0.36
dense dry sand [under base]	1.75	0.53	43	0.34

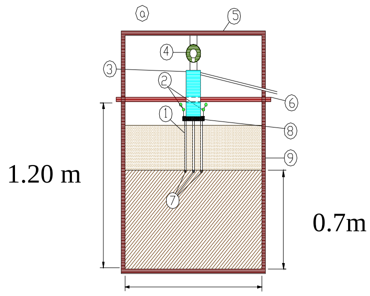
The test conditions were imposed, and the pile was free to settle as the sand was placed around it, and the initial residual load distribution was neglected. The cap was relatively rigid which led to equal settlement of all the piles in the group and avoided differential settlement, as shown in schematic diagram figure (3). The sand was deposited in 5 layers under the base of the piles and each layer was tamped by a tamper to achieve a relative density of approximately 93 %, then the piles were erected and tested in two cases.

First case - the pile groups were placed and the dry sand poured around the piles-until the required embedment length without any compacting with an initial relative density of approximately 58 % to be in the same conditions as in-situ.

Second case - the pile groups were placed and the dry sand poured around the piles in layers and every layer was compacted by a tamper to achieve a relative density of approximately 84 %. Special care was taken to compact the sand layers manually to make the sand as uniform as possible.

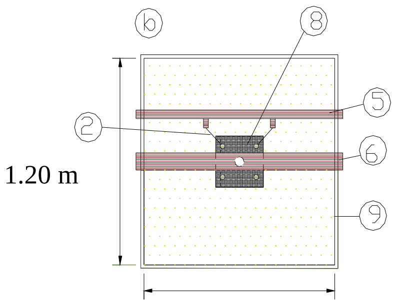
The loading tests were maintained for the same time interval -quick load test- as the previous interval.

Each load increment was applied for 2 minutes.The total load on the group was controlled by the load cell and was applied by a hydraulic jack pushing against a steel reaction beam as shown in figure (3) and increased until the rupture load of the soil was reached. Three dial gauges were placed on the pile cap to measure the pile cap settlements. Temperature variations in the laboratory were $\mp 3^0$ C.



ELEVATION

1- MODEL PILE
2- DIAL GAGE
3- HYDRAULIC JACK
4- LOAD CELL.
5- STEEL BEAM
6- GIRDER
7- LOAD CELL
8- CAP
9- TIMBER TANK



PLAN

FIG..3. General details of test apparatus

[Schematic Diagram]

3. Test Results

The results based on the tests of 5 and 9-pile groups in coarse homogenous dry sand with different initial relative densities around the piles, show that the base resistance (end bearing capacity) of pile groups is dependent on the number of piles in the group, the pile spacing and, the initial relative density, the void ratio and the density of sand around the base of the piles.

Figures (4) and (5) shows that the base resistance of the central pile in the 5-pile groups with pile spacing [S = 2.5 d] is equal to 30 % and 26 % of the total base bearing capacities of the pile groups in the first case and second case respectively, whereas it is 26 % in the first case and 24 % in the second case for pile spacing [S = 5 d] as shown in figures (4) and (5). The base resistance of the corner pile in the 5-pile groups is equal to 18 % approximately in the two above cases, as shown in figures (4) and (5).

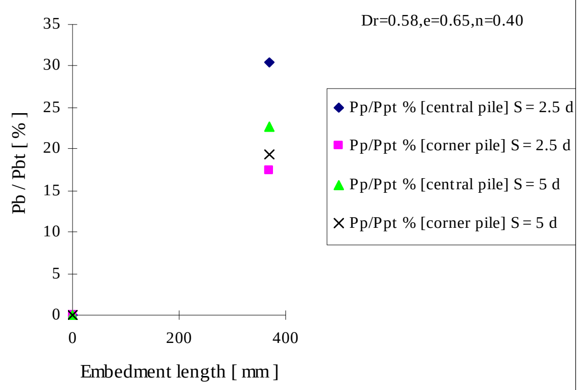


FIG. 4 Shows the percentage of the base bearing capacity of individual piles tin 5-smooth model pile groups in medium dense dry sand

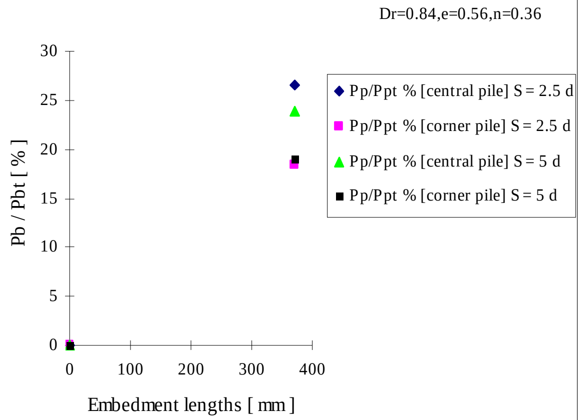


FIG. 5 Shows the percentage of the base bearing capacity of individual piles tin 5-smooth model pile groups in dense dry sand

Figures (6) and (7) establishes the summary of laboratory load test results for 9-smooth model pile groups.

Figure (6) shows that the base resistance of the central pile in the 9- pile groups is equal to 20 % of the base bearing capacity of the pile group in the first case for pile spacing [S = 2.5 d], and it is equal to 14 % on average for [S = 5 d].

In the second case the proportion is equal to 18 % for pile spacing [S = 2.5 d] and 16 % at pile spacing [S = 5 d] as shown in figure (7).

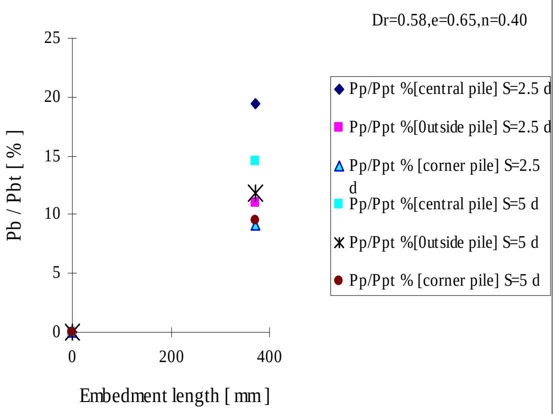


FIG. 6 Shows the percentage of the base bearing capacity of individual piles tin 9-smooth model pile groups in medium dense dry sand

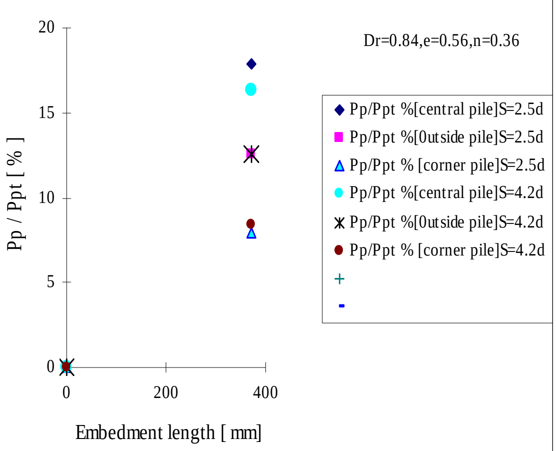


FIG. 7 Shows the percentage of the base bearing capacity of individual piles tin 9-smooth model pile groups in dense dry sand

The average base resistance of the outside pile to the base bearing capacity of the pile groups is equal to 12 % approximately for two conditions of sand around the piles and with two different pile spacing, whereas for the corner piles the proportion is equal to 9 % for two cases as shown in figures (6) and (7).

The very significant increase of base resistance in the 5 and 9-pile groups-especially in the second case-results from the compacted soil fenced by the corner piles and the loading effect of the neighbouring piles as shown in figure (8) for Overlapping of compacted zones.

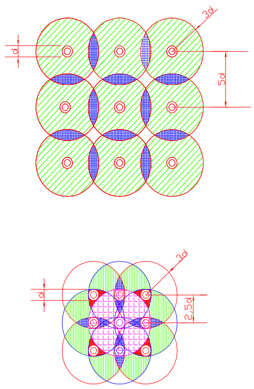


FIG..8. Overlapping of compacted zones of different pile spacing [Petrasovits]

4. Conclusion

On the basis of the tests which were done on the pile groups, the following conclusions can be made:

The average base resistance of the central pile in 5-pile groups is greater than that of the corner pile by approximately 25 % in the case of [S = 5 d] and by approximately 50 % in the case of [S = 2.5 d].

The central pile in the 5-pile groups has higher effectiveness for increasing the bearing capacity in the second case [compacted sand around the piles] than in the first case [medium dense sand] by 50 % on average

The load bearing capacity of pile groups in the second case [compacted sand around the piles] is approximately twice that in the first case [medium dense sand].

The significant increase in the load bearing capacity of the central pile increases with decreasing pile spacing.

The increase in bearing capacity of a central pile comes from the increase of base resistance

The base resistance of the central pile in a 5-pile group with pile spacing [S = 2.5 d] is equal to 30 % and 26 % of the total base bearing capacity of the pile groups in medium and dense dry sand, .respectively.

The base resistance of the central pile in a 5-pile group with pile spacing [S = 5 d] is equal to 26 % and 24 % of the total base bearing capacity of the pile groups in medium and dense dry sand.

The base resistance of the corner pile in 5-pile groups is equal to 18 % on average of the total base bearing capacity of pile group in medium and dense dry sand.

The base resistance of the central pile in 9-pile groups is equal to 20 % and 14 % of the total base bearing capacity of the pile group for pile spacing

[S = 2.5 d] and [S = 5 d], respectively.

The base resistance of an outside pile is equal to 12 % approximately of the total base bearing capacity of a 9-pile group, where, for a corner pile it is equal to 9 % for two different pile spacing and sand densities around the piles.

In general the base resistance of the central pile is less effective in longer pile spacing.

Very significant increase of base resistance results from the compacted soil fenced by the outside and corner piles and the loading effect of the neighbouring piles.

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