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BACK-ANALYSIS FOR DESIGN PARAMETERS OF LARGE DIAMETER BORED PILES

Werasak Raongjant[1a] , Meng Jing[1b]

[1]Department of Civil Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, 12110, Thailand.

[a]werasak.r@en.rmutt.ac.th, [b]meng.j@en.rmutt.ac.th

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Abstract. Field test data from three instrumented large diameter bored piles in Pattaya city of Thailand were analyzed to study the behavior of load transfer mechanism from the pile to soil. The pile load test data were obtained from conventional static load test. These bored piles used for conventional static load test have the same diameter of 0.80 m and different length in the range of 25 m to 32 m. Results from back-analysis found that the skin friction resistance, β, has the value between 0.20 and 0.64 and the bearing capacity at end of piles, N_q, which is in the range of 10 to 150, is much lower than the theoretical values proposed by other researchers before.

Introduction

Pattaya City is a very famous tourist resort in Thailand. Due to the particular ground conditions, large diameter bored piles may be used when larger and higher buildings need to be constructed. In the past 30 years, some study work were focus on the design parameters such as the negative skin friction and bearing capacity of piled foundations in Thailand.

Sambhandaraksa proposed the method to estimate the capacity of small cross section driven piles in the upper clay layer and sand [1]. However, for spun piles of 600 mm and 800 mm diameter, it appeared that the capacity computed from this approach needs to be enlarged [2]. Balasubramaniam used the similar method to study the relationship between average shaft friction and the average effective overburden pressure. The β values ranged from 0.17 to 0.48 with an average value of 0.33 [3]. Lin et al. illustrate mobilization of skin friction and end bearing in the Bangkok sub-soils for the design of bored piles. These data are back calculated from several instrumented bored piled load tests and can be used in deformation analysis of piled foundations and piled raft foundations [4].

In this study, based on the data gathered from standard penetration test for three large diameter bored piles onsite of Pattaya city, Thailand, back-analysis were processed to get the appropriate parameters for design.

Characteristics of the ground in Pattaya city

In Pattaya city, soil is mostly engendered by the decomposition of igneous rocks. The top layer of coarse sand is quite loose with uncertain thickness. Above sand may be the layer of marine silt. From the top down to the granite layer at the depth of 20.50 meters to 44 meters, there are the layer of loose sand in thickness of about 2~3 meters, the layer of medium dense sand at a depth of about 2~9 meters, the layer of dense sand at a depth of approximately 7.50 to 16.50 meters and the layer of very dense sand at a depth of about 10.50 to 29.50 meters in sequence.

Static load test of piles

Testing data were collected from the conventional static load test of three well instrumented piles in different site of Pattaya city, Thailand. All the three piles were large diameter bored piles, as shown in Table 1.

Table 1 Piles for static load test

Piles	Diameter [m]	Length [m]	Max. load [$\times 10^3$ kg]	Soil at pile tip	Instruments	Pile site
P-1	0.80	25	2040	very dense sand	24 VWSG at seven level 5 Telltale at seven level	The lofts South shore
P-2	0.80	30.50	2750	rock	32 VWSG at seven level 7 Telltale at seven level	The lofts South shore
P-3	0.80	32	2752.29	rock	28 VWSG at seven level 6 Telltale at seven level	Ocean 1 Tower

The standard penetration test was done after the completion of the installation of piles at least 30 to 90 days, or at least 3 - 30 days according to ASTM D 3689-83, in order that the soil around the pile can recover its strength at first. Pile internal forces, strain and settlement were measured to study the transfer mechanism and geotechnical resistance distribution state of piles. Table 2 displays the test results of standard penetration test, *SPT-N* Value and the angle of internal friction (Φ').

Table 2 Results of standard penetration test

Depth [m]	Description of soil	*SPT-N*	Φ'
1 ~ 3	loose sand	2-8	29
2 ~ 9	medium dense sand	14-29	37
7.50 ~ 16.50	dense sand	29-46	40
10.50 ~ 29.50	very dense sand	> 50	-
(20.50~29.50) ~ 44	rock	-	-

Data back-analysis

The required parameters for estimating the load bearing capacity of piles in general are the effective overburden pressure (σ'_{vi}) and the angle of internal friction (Φ') for each sand layers. The various parameters are depends on the shape and size of the piles, the construction method of the piles and the load application (working load) of the pile [5].

Estimation of the friction force on the side of the pile. In order to estimate the friction force on the side of the pile in the sand, the relationship between the friction factor, β, which is equal to K_s $\tan\delta'$, and the angle of internal friction, (Φ'), are used here [6]. Then the value of unit skin friction in the sand layers, f_s, can be inverse analyzed by the equation

$$\beta = K_s \tan\delta' = f_s / \sigma'_{vi} \quad (1)$$

$$f_s = \sigma'_{vi} K_s \tan\delta' \quad (2)$$

in which K_s is the coefficient of lateral earth pressure of soil; δ' is the friction between the surface of pile and the soil; σ'_{vi} is the vertical effective overburden pressure at the middle of sand layer; f_s is the unit friction force to resist the settlement of the pile under the maximum theory load, which is not reach the ultimate loading capacity of pile, Q_{ult}. [7]. The value of Φ' is got from the relationship between the angle of Φ' and the N from the SPT test after correction by the results of σ'_{vi}.

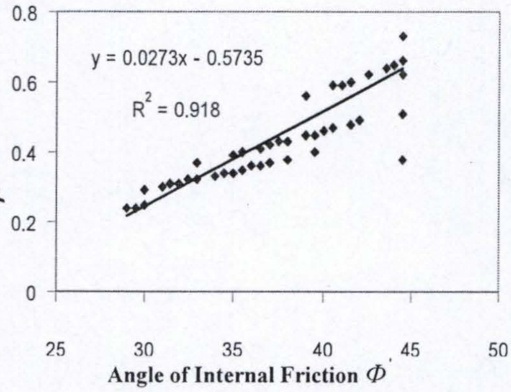

Fig. 1 The value of friction factor, β

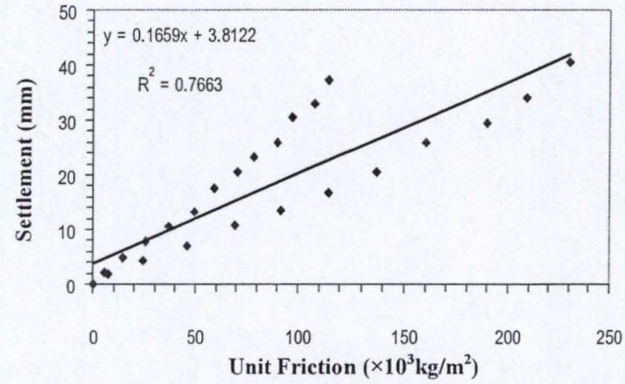

Fig.2 The unit friction at the depth of -24.50 to-31.125m

It can be seen from Fig. 1 that, the correlation between the friction factor, β, and the angle of internal friction, Φ', is likely in the straight line, where β is in the range of 0.20 to 0.64 correspondingly with Φ' in the value of 29 to 44.5 degrees. The correlating coefficients R^2 is equal to 0.918, which means that value of β, can be estimated by using this relationship with good precision. Then the value of f_s can be got through Eq.2, without static load test of piles in field. Fig. 2 shows the comparison of test results and calculated results of value f_s at pile tips. It can be seen that the correlating coefficients R^2 is equal to 0.7663, which means that using the relationship presented in Fig. 1 can get the parameters for pile design very easily with acceptable precision.

Estimation of bearing capacity at the end of piles. For the pile with the end in sand, the relationship between the mobilized bearing capacity factor, N_q, and the angle of internal friction, Φ', is as follows.

$$\text{Mobilized } N_q = q_E / \sigma'_{vi} \tag{3}$$

in which, q_E is the unit end bearing force corresponding to the settlement of the pile.

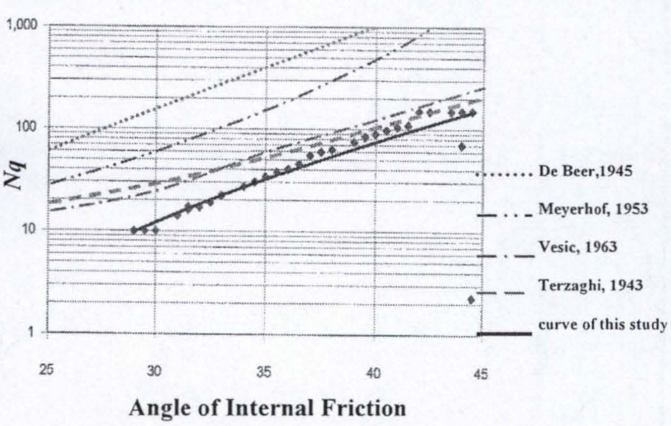

Fig.3 The Bearing Capacity Factor, N_q

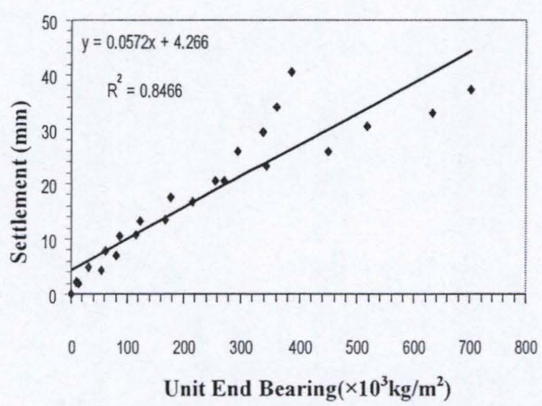

Fig.4 The unit end bearing at the pile tip

The results were expressed in terms of the relationship between the bearing capacity factor, N_q, and the angle of internal friction of the sand in Fig.3, which showed that the mobilized N_q was likely in the range of 10 to 150, much less than the values got by foreign researchers before [8]. It may be caused by the different force transfer system of the pile in Pattaya. From the test results, it can be seen that the load taken by the pile surface through friction is much higher than that taken by the end of pile. Averagely 85.3% of total load was transferd through skin friction. Fig.4 shows the comparison of test results and calculated results of value q_E at pile tips. It can be seen that the correlating coefficients R^2 is equal to 0.8466, which means that using the N_q presented in Fig. 3 can get the parameters for pile design very easily with acceptable precision.

Conclusions

This paper summarizes the role of data back-analysis method and pile load tests in Pattaya city, Thailand, and their influence on estimating the bearing capacity of large diameter bored piles. The back-analysis was based on the data of conventional static pile load test of three large diameter bored piles. It is shown that for sandy soil in Pattaya city, where Φ' is the value of 29 to 44.5 degrees, the friction factor β is in the value range of 0.20 to 0.64, correspondingly, with the linear relationship. Bearing capacity factor, N_q, is equal to 10 to 150 which is little lower than the value proposed in the past research. Because there are less information on the soil in Pattaya city, Thailand, the conclusion presented in this paper through data back-analysis method can provide acceptable parameters to design works of large diameter bored piles.

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