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EXTENDED ABSTRACT

Estimation of Bearing Capacity of Bored Piles Using CPT and SPT Direct Results and Compared with Static Pile Load Tests- The Case Study

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1. Introduction

In marine environments such as beaches and ports, typically, the type of soil layers are soft, thus using piles to retrofit (strengthen) the soil in this area is essential for constructing different structures such as the quay walls. Bored concrete piles are commonly used in these marine areas; consequently, determining the final bearing capacity of this type of pile is necessary for the safe design of deep foundations. Whereas, the exact prediction of the ultimate bearing capacity of the piles is always a challenge for engineering designers who can achieve it by using various approaches, for instance, pile load tests, dynamic analysis, static analysis, and in situ testing. The cone penetration test (CPTu) is the most effective in situ technique for describing soil characteristics. The CPTu is an efficient, simple, fast, reliable, and economical test that can provide continuous data of subsurface soil properties. Besides, the standard Penetration Test (SPT) is one of the most common and economical field tests used during the structures' ground investigations. Not only is it used for main applications in soil characterization, but also SPT N-Value is widely used for the design of structural foundations and other underground structures, especially for the bearing capacity of the piles.

2. Methodology

There are two categories of information about the ShahidRajaee port project in this study. The first category of CPT and SPT testing data are included cone tip resistance (q_c) and sleeve friction (fs) during penetration and the N- value in the SPT test. The second category of data is included load capacities computed by static tests, which are performed on the piles in situ. In the current survey, the Unipile software was used to calculate the bearing capacity of the piles by using the CPT and the SPT methods. For the CPT methods, the four approaches of Schmertmann- Nottingham (1978), Beringen- De Ruiter (1979), Bustamante- Gianeselli (1982), and Eslami – Fellenius (1997) and for the SPT methods, the two approaches of Meyerhof (2017) and O'Neill- Reese (2011) are used to determine the bearing capacity of the piles. The bearing capacity of the piles is calculated by using the CPT and SPT data for each of the methods as mentioned earlier (Q_m). Furthermore, the bearing capacity of the piles is calculated on a real scale by using the methods performed in situ (Q_p). Then it is plotted in a graph with Qm and Qp values on its vertical and horizontal axis, and each point that is determined with the pair (Q_m, Q_p) is shown on this coordinate system. Then the best fit of these points, which passes through the origin of this coordinate system determined (Q_{fit}). Since the ideal state of these results is Q_p=Q_m, the ideal fit also passes with a slope equal to one (Q_p=Q_m), whether it passes through the origin. In the following, for each proposed method, by comparing these two fittings and obtaining the coefficient of determination, these methods are prioritized, and the best method is found for pile bearing capacity by using CPT and SPT data.

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3. Results and discussion

The four statistical methods are used to evaluate the bearing capacity of the piles, which are obtained from CPTu and SPT tests. For this purpose, the predicted bearing capacity of the CPTu and SPT test methods (Q_p) and measured the bearing capacity of the static loading test of the pile (Q_m) were evaluated. The statistical methods such as the best-fitted line which is passed of origin for Q_p versus Qm, geometric mean and standard deviation for the Q_p/Q_m ratio, the cumulative probability in P50 and P90 for the Q_p/Q_m ratio, the accuracy level of 20 percent derived from the histogram and the normal distribution diagram for the Q_p/Q_m ratio are used to compare and prioritize various methods based on CPTu and SPT data for obtaining the bearing capacity of the piles. The methods for calculating the bearing capacity of the piles are prioritized based on statistical effort. For this purpose, the lowest level (R1=1) is assigned to the most agreement method in each comparison, and then the remained methods based on their compliance are assigned to the levels 4R1 and 2R1 for methods based on CPTu and SPT, respectively. According to each statistical method, assigned an index of 1 to 6 for each method. Finally, a prioritization based on the total priorities with the ranking index RI=R1+R2+R3+R4+R5+R6 is calculated for each method. Consequently, the best method is obtained based on the lowest value of the priority sum. The results of these priorities are presented in Table 1 and Table 2, respectively. In these tables, by summing up all priorities, it can be seen priorities of the cone penetration methods for determining the bearing capacity of the piles in the order that 1) Schmertmann- Nottingham, 2) Bustamante- Gianeselli, 3) Eslami- Fellenius, 4) Beringen- De Ruiter, respectively. Also, these priorities of standard penetration methods for determining the capacity of bearing piles are in the order that 1) Meyerhof, 2) O'Neill and Reese, respectively.

Table 1. Summary results of different bearing capacity of pile methods based on CPTu data

	best-fit line			geometric mean		standard deviation		cumulative probabilities50%		cumulative probabilities		accuracy level equals 20%	RI	Final rank
	Q_p/Q_m	R^2	R1	μ'	R2	σ	R3	P_{50}	R4	ΔP	R5	R6		
Eslami	0.39	0.8	4	0.38	3	0.09	2	0.66	1	0.91	2	3	15	3
Schmertmann	0.7	0.44	1	0.58	1	0.46	3	0.83	3	1.93	4	1	13	1
Beringen	0.53	0.28	2	0.36	4	0.5	4	0.45	4	1.63	3	2	19	4
Bustamante	0.41	0.945	3	0.41	2	0.05	1	0.74	2	0.9	1	4	13	2

Table 2. Summary results of different bearing capacity of pile methods based on SPT data

	best-fit line			geometric mean		standard deviation		cumulative probabilities50%		cumulative probabilities		accuracy level equals 20%	RI	Final rank
	Q_p/Q_m	R^2	R1	μ'	R2	σ	R3	P_{50}	R4	ΔP	R5	R6		
Meyerhof	0.75	0.97	1	0.74	1	0.06	2	2.15	2	1.58	2	1	9	1
O'Neill	0.43	0.97	2	0.43	2	0.03	1	1.35	1	0.83	1	2	9	2

4. Conclusions

In the current survey, the bearing capacity of five boring reinforced concrete piles with a circular cross-section, which was constructed in Shahid Rajaee Port Complex (SRPC) that is located on the west side of Bandarabbas city, south of Iran, and on the north coast of the Persian Gulf, are investigated.

The bearing capacity is of the piles by using cone penetration test results (CPTu), and the standard penetration test (SPT) methods are the measured bearing capacity of the piles subject to static loads.

In all cases, the Cone Penetration Test (CPTu), the Standard Penetration Test (SPT), and the piles subject to static loads test are conducted on the piles, and the final bearing capacity of the piles (Q_m) is obtained. The bearing capacity of the piles was calculated by using the CPTu and SPT and the aforementioned direct methods (Q_p). In order to evaluate the bearing capacity of the piles, the different above-mentioned statistical methods are used. Finally, by summing up all priorities, the priorities of the cone penetration methods for determining the bearing capacity of the piles are in the order that 1) Schmertmann- Nottingham, 2) Bustamante- Gianeselli, 3) Eslami- Fellenius, 4) Beringen- De Ruiter, respectively. Besides, these priorities of standard penetration methods for determining the capacity of bearing piles are in the order that 1. Meyerhof, 2. O'Neill and Reese, respectively.

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