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Determination of Bearing Capacity of Steel Pipe Piles in Sandy Soil using Static Compressive Load Test

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ABSTRACT: Piles are relatively long structural foundation members that are used to transmit loads from soil layers with low bearing capacity (or high settlement) to deep soil layers with high bearing capacity. In foundation design, determination of pile bearing capacity is considered as a complex issue. In this paper, the bearing capacity of steel pipe piles in sandy soil is studied using the results of static compressive load test. Piles were installed in soil using the jacking method. In this method, at first, a hydraulic jack was applied for installing piles and then, it was used for applying the compressive load required in the static load test. After recording data, the values of bearing capacity of the piles were compared with the values calculated from analytical methods. Then, the values of the friction capacity of piles were evaluated using the results of the tension test. The results showed that due to the effects of soil plug on the bearing capacity of piles and installing piles using the jacking method, the obtained values of bearing capacity of the piles are much than their analytical ones. Moreover, the results indicate the effect of frictional resistance on the ultimate bearing capacity of the piles.

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1. INTRODUCTION

Generally, investigations about the behavior of piles under compressive load have been performed in the laboratories, which are not able to reflect the real conditions of the site. Therefore, it is necessary to use a pile load test in site to study pile behavior especially in granular soils that are sensitive to disturbance. On the other hand, jacking method is a popular method for installing piles in soil because this method does not generate any noise during pile installation. The results of studies [1-3] on instrumented open-ended model pipe piles that were jacked into loose dry sand in a large testing chamber showed that end bearing capacity of pipe piles is due to plug and annular capacities of pile tip.

Moreover, frictional resistance is mobilized either in the inner or in the outer side of the pile. Also, plug capacity has a considerable effect on the resistance of pipe piles and causes open-ended pipe piles to behave similar to close-ended ones. This issue can lead to widespread use of open-ended pipe piles because these piles are economical, and their installation is easy. Paik and Lee [4] stated that plug capacity is primarily affected by relative density and lateral stress acting on the pile tip, but it is nearly unaffected by the vertical stress. Furthermore, about 90% of the plug resistance is transferred to the soil plug within the zone of 3 times the inner diameter of the pile from the pile tip, irrespective of soil conditions. They also showed that the earth pressure coefficient in the soil plug tends to decrease with an increase in the penetration depth, and it increases with an increase in the initial lateral stress.

In this research, bearing capacity and frictional resistance of open-ended steel pipe piles in sandy soil and the effect of soil plug on the bearing capacity of these piles are studied. Moreover, the results of pile load tests are compared with the results obtained by analytical methods.

2. EXPERIMENTAL INVESTIGATION

In this section, at first, the characterization of the site and piles are studied and then, the procedure of the pile load test is explained.

2.1. Site Characterization

The site for performing pile load tests is located in Mazandaran province, Chaksar region. The results of gradation on soil showed that the soil is poorly graded sand (SP) according to the Unified Soil Classification System (USCS) and has a unit weight of γ = 17.5 kN/m^3. The groundwater level is located 3 meters below ground level. Table 1 presents the physical and mechanical properties of

Table 1. Soil properties

N_{avg}	γ(kN/m^3)	Ø(°)	G_S	c(kPa)
19	17.5	33	2.73	1

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Table 2. Properties of piles

Pile	L (cm)	D_{out} (cm)	D_{in} (cm)	A_{in} (cm^2)	A_{st} (cm^2)
A	210	14	13.4	141	12.9
B	195	11.5	10.9	93.3	10.5
C	140	7.8	7.2	40.7	7.1
D	90	4.9	4.3	14.5	4.3

Fig.1. A view of pile load test

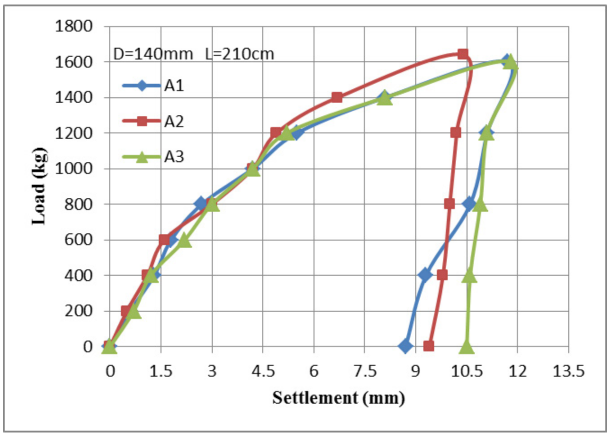

Fig.2. Results of load tests on piles type A

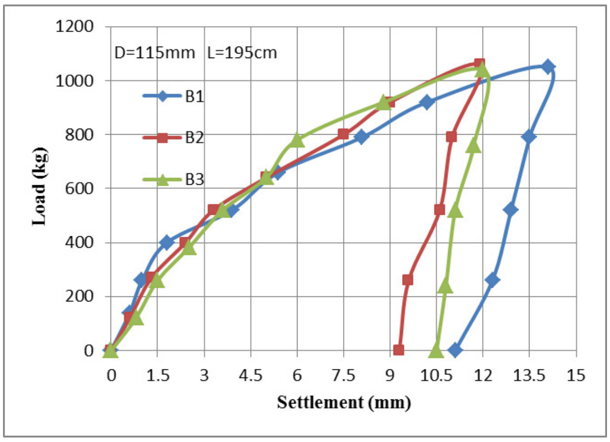

Fig.3. Results of load tests on piles type B

soil in which N_{avg}, Ø, G_S and c represent the average standard penetration number, internal friction angle, specific gravity and cohesion, respectively.

2.2. Properties of Piles

Table 2 shows properties of piles in which A_{st} is the pile area, A_{in} is the area of the hollow section of pile, L is the pile length, D_{out} is the outer diameter of pile and D_{in} is the inner diameter of the pile. The piles are made up of steel and named A, B, C and D with the L/D_{out} of 15, 16.9, 17.9 and 18.3, respectively.

2.3. Pile Load Test

Pile load tests were performed according to ASTM-D1143 [5]. The piles were loaded to a maximum maintained load of 200 % of the anticipated design load for tests, applying the load in increments of 25 % of the design load. Each load increment was maintained until the rate of axial movement does not exceed 0.25 mm per hour, with a minimum time adequate to verify this movement rate based on the accuracy of the movement indicator readings, and with a maximum of 2 hours. Loading is continued until progressive movement occurs, or total axial movement reaches 15 % of the pile diameter. Each type of pile was installed and tested 3 times (such as A1, A2 and A3). Figure 1 shows a view of the pile load test.

3. RESULTS AND DISCUSSION

In this section, load-settlement curves obtained from pile load tests are presented and analyzed.

3.1. Results of Load Tests on Piles Type A

To determine the ultimate load, a technique called the "intersection of tangents" was used in this study. This is accomplished by graphically constructing two tangent lines. One line is drawn tangent to the second straight line portion of the load curve. The other line is drawn tangent to the initial straight-line portion of the load-deflection curve, which is beyond the curved or non-linear portion of the load-deflection curve. The point where the two tangents intersect identifies an estimate of the ultimate load. Figure 2 shows the results of load tests on piles type A.

3.2. Results of Load Tests on Piles Type B

Figure 3 shows the results of load tests on piles type B. It is observed that the ultimate settlement of B1 has been more than B2 and B3 which can be due to the generation of soil plug. However, the behaviors of piles are similar which shows repeatability of load tests.

3.3. Results of Load Tests on Piles Type C

Figure 4 shows the results of load tests on piles type C. It is observed that load-settlement variations in these three piles are approximately similar to each other.

3.4. Results of Load Tests on Piles Type D

Figure 5 shows results of load tests on piles type D. The

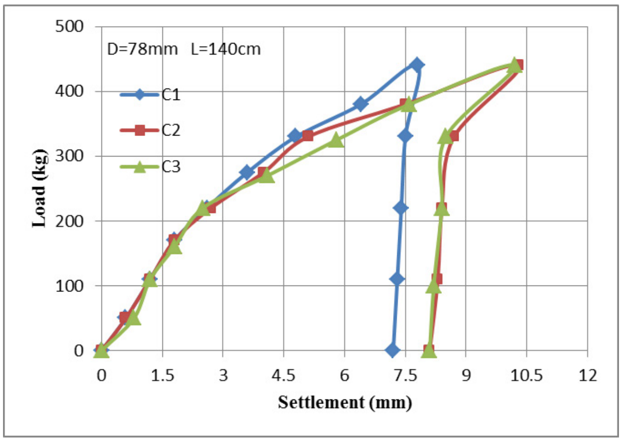

Fig.4. Results of load tests on piles type C

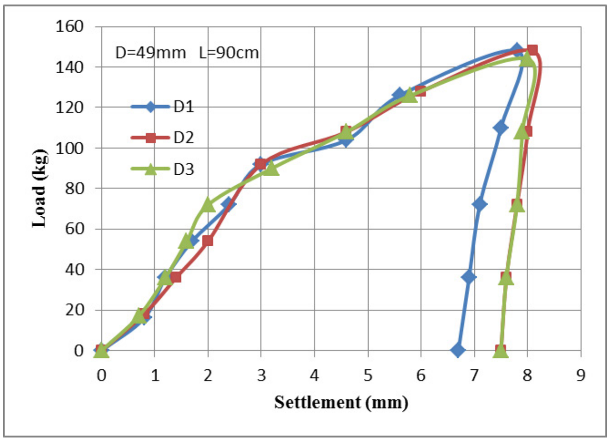

Fig.5. Results of load tests on piles type D

Table 3. Bearing capacity and settlement of piles

Pile	Average bearing capacity from tests (kg)	Average bearing capacity from analytical methods (kg)	Average ratio of settlement to outer diameter of pile (%)
A	1171.7	859	2.3
B	664.1	550	2.8
C	277.6	228	3.7
D	104.2	76	6.2

Table 4. Soil plug

Pile	Pile length (cm)	Plug length (cm)	Unit weight of soil plug (kN/m^3)
A	210	96	21.4
B	195	67	19.8
C	140	50	19.3
D	90	30	18.75

Table 5. Frictional bearing capacity of piles

Pile	Average bearing capacity from tests (kg)	Average frictional bearing capacity (kg)[7]	Ratio of column 3 to column 2 (%)
A	1171.7	600.5	51.2
B	664.1	300.2	45.1
C	277.6	74.4	26.8
D	104.2	24.7	23.7

load-settlement curves of these piles are similar to each other, which this issue shows repeatability of load tests.

3.5. Interpretation of the obtained results

Table 3 shows the comparison of the results of pile load tests with ones obtained by analytical methods. It is clear that bearing capacity of piles A, B, C and D is 36, 20, 21 and 37% more than ones obtained by analytical methods, respectively. This can be due to the effect of soil plug on the bearing capacity of piles. Another factor can be due to the installation of piles by jacking method, which minimizes soil disturbance and causes bearing capacities of piles to reach their real values. This issue has not been considered in conventional analytical methods. After removing piles, length and unit weight of soil plug were calculated. As seen in Table 4, length and unit weight of soil plug increase with increasing pile length.

3.6. Calculation of frictional bearing capacity

In most of deep foundations, shaft resistance is about the same for uplift and compression loads [6]. Hence, the results of tension tests performed on these piles [7] can be used for estimation of their frictional resistance. Table 5 shows the frictional bearing capacity of piles.

4. CONCLUSIONS

In this study, to determine the bearing capacity of open-ended pipe piles that were installed in sandy soil using jacking method, several compressive pile load tests were carried out according to ASTM-D1143. The results showed that bearing capacity values of open-ended pipe piles are averagely more than their values obtained by analytical methods, which can be due to the effect of soil plug on the bearing capacity of piles and also the effect of installing piles using jacking method. Besides, the results show that frictional bearing capacity increases with increasing diameter of open-ended pipe piles.

REFERENCES

[1] Lehane, B., and Gavin, K.G., 2001. "Base Resistance of Jacked Pipe Piles in Sand". *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, 123(10), pp. 473–480.

[2] O'Neill, M.W., 2001. "Side Resistance in Piles and Drilled Shafts". *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, 127(1), pp. 3-16.

[3] Lehane, B.M., Jardine, R.J., Bond, A.J., and Frank, R., 1993. "Mechanisms of Shaft Friction in Sand from Instrumented Pile Tests". *Journal of Geotechnical Engineering*, 119(1), pp. 19–35.

[4] Paik, K.H., and Lee, S.R., 1993. "Behavior of Soil Plugs in Open-ended Model Piles Driven into Sands". *Marine Georesources Geotechnology*, 11(4), pp. 353–373.

[5] ASTM-D1143, 1981. *Standard Test Method for Piles under Static Axial Compressive Load*, American Society for Testing and Materials. USA.

[6] Parthipan, N., and Kumar, M., 2017. "Experimental Study on Uplift Load Carrying Capacity of Steel Pile in Sand". *International Journal of Science and Research*, 6(5), pp. 2682-2684.

[7] Sharifi, A., 2016. "A Study on the Frictional Resistance of Steel Pipe Piles under Tension in Sandy Soil". MSc. Thesis, Pardisan University, (in Persian).

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