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

doi:10.3233/978-1-61499-656-9-3547

Application of dynamic load test for estimating bearing capacity of large diameter steel pipe piles

Application d'essai de charge dynamique pour estimant la capasité portante des pieux tubulaires en acier de diamètre grande

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1 INTRODUCTION

The load tests of piles can be classified into static and dynamic load tests. The latter includes the dynamic load test by hammering and the rapid load test using explosives, which have some advantages on the time efficiency and economics, although the reliability should be confirmed. In this paper, a case history of the dynamic load test by hammering is shown for estimating the bearing capacity of large steel pipe piles, taking the foundations of the Kobe Sky bridge as an example, followed by the discussions on the applicability of the dynamic load test.

2 OUTLINE OF KOBE SKY BRIDGE AND LOAD TEST OF PILES

The Kobe Sky bridge is the access bridge to the new Kobe Airport Island from the Port Island, Japan. The length is 1180 m. The superstructure is composed of 9 spans and the substructure is constructed by the submerged steel pier foundation. Each pier is composed of 49 steel pipe piles of 1.5 m in diameter and 54-60 m in length.

As for the ground formation, the uppermost is the soft clay layer of Recent Deposits of about 20 m thick. The underlain gravel layer of Pleistocene is the bearing layer for piles. Among the 8 steel pier foundations, dynamic load tests are applied on the 3 piers for optimizing the designed bearing capacity of steel pipe piles, and the other 2 piers for checking the quality of pile performance during execution.

The measuring system using computer is used during dynamic load tests. Two transducers which are composed of accelerometer and strain gauge are installed on pile surface at around pile top, and the data are collected to computer through the junction box.

To accurately confirm the required curing period for large diameter steel pipe piles, the dynamic load tests are carried out several times during 23 days after pile execution. To avoid the effect of soil disturbance due to repeated use of a pile, a certain number of piles are used.

3 TEST RESULTS AND CONSIDERATIONS

Comparing the relationships between end bearing capacity and penetration into bearing layer in the Specifications for Highway Bridges with the measured data in this case history, the measured end bearing capacity has only about 30% of the fully plugging effect.

Based on the measured variation of normalized skin friction of pile with the curing period, it is seen that the recovery of skin friction is caused gradually. Also, as for sandy and gravel layers, the measured data reach the designed skin friction in about 5 days, as expected in the Specifications. In contrast, as for clayey soil layers, they reach about 70% of the designed one even in 14 days, which is significantly less than expected in the Specifications. Extending the trends of measured data, it seems that around one month of curing period might be required to reach the designed one.

Based on the measured relationships between penetration and normalized pile end resistance, considering the insufficient plugging effect, in such large penetration as 30-40 mm, the plastic deformation of soils around pile surface might be induced, reducing the skin friction.

Also, based on the measured relationships between normalized pile end resistance and transmitted energy by hammer, in which the curing period is the variable parameter, only in the case of the initial impact with 3 to 4 times the conventional transmitted energy of hammering, the measured pile end resistance can be confirmed to reach the designed one. In contrast, in case of conventional smaller energy, it is difficult to reach the designed one. This is because the recovery of skin friction in sandy and gravel layers is rather fast, resulting in the less energy transmission to pile end.

Consequently, it is recommended that, to confirm the end bearing resistance of pile by the dynamic load test, a greater capacity of hammer than 3 to 4 times the conventional one should be used and measured in the initial impact.

4 CONCLUSIONS

The main conclusions in this paper are summarized in the following points on the bearing capacity of large diameter steel pipe piles.

(1) The dynamic load test by hammering can be effectively applied for estimating the bearing capacity of large diameter steel pipe piles.
(2) The end bearing capacity of large diameter steel pipe piles has only about 30% of the fully plugging effect.
(3) For sandy and gravel layers, the designed skin friction is measured after curing of about 5 days, as expected in the Specifications. In contrast, for clayey soil layers, the measured skin friction is significantly less than expected in the Specifications. Consequently, it is suggested in this case history that around one month of curing period might be required to reach the designed one.
(4) In such large penetration as 30 to 40 mm into bearing layer, and/or in the case of the initial impact with 3 to 4 times the conventional transmitted energy of hammering, the designed pile end resistance can be measured. Consequently, it is recommended that, to confirm the end bearing resistance of pile by the dynamic load test, a greater capacity of hammer than several times the conventional one should be used and measured in the initial impact, so as to induce the plastic deformation in soils around pile surface.