Study on Pressing Pipe Pile into Complicated Foundation

Liu Haitao1*    Sun Jie1
1Construction Economy and Management Institute, Shanghai Urban Construction Vocational College, Shanghai, 200486, China
*Corresponding author’s e-mail: liuhaitao@succ.edu.cn

Abstract. Pre-stress high-strength concrete piles have been widely used in many constructions in recent years, and it was relatively difficult to press pipe pile statically into complicated ground. With mud of large proportion protecting holes, pushing piles into Pre-cited hole in sandy ground was introduced in this assay, and the requirements of engineering demands were fully met after a strict on-site test, which could be a worthy reference for the similar projects.

1. Introduction
The piles of pre-stress high-strength concrete have been widely used in many constructions in recent years. With the development of basic theory and engineering practice, the applied scope of pushing pre-stress high-strength concrete pile in ground gradually expanded, and there have been some successful cases in thin sand layer [1] or gravel layer [2].

The standard penetration test and static cone penetration test in dense sand layer showed that it was not a easy thing to press pre-stress high-strength concrete pile in complicated foundation. Pre-guide-hole technology in pile position is an effective measure to solve the difficult problem of jacking pile in sand [2-4], and the constructing process of pre-guide hole and jacking pile would easily cause collapse in sand ground which made it extremely difficult to sink pile in soil[5-8]. Combining with an engineering example, slurry pre-guide-hole construction techniques would be introduced to jack pre-stress high-strength concrete pile in sand ground in this assay.

2. General engineering geology
The construction is a high-rise residential of on the ground 28 layers and underground 1 layer, located in northeast district in Zhengzhou. The foundation is buried deep below ground 6 m, and the underground water level is 6 ~ 7 m under the surface . The project is located in the alluvial plain of the Yellow River, and the main soils from top to bottom are distributed as follows:

First layer: miscellaneous soil, formed of construction waste and domestic waste, with an average thickness of 0.8m;
Second layer: silty clay, locally inter bedded with silty layer, with an average thickness of 4.1m;
Third layer: fine sand, medium dense to dense, saturated, with an average thickness of 25.2m;
Fourth layer: hard plastic silty soil, clipped in several fine sand layers, with an average thickness of 50m.

Considering the foundation form of high-rise residential in Zhengzhou area, and on the basis of safe, applicable, economic, durable principles, pre-stress high-strength concrete pile, filling pile and composite foundation of CFG pile were compared to find a better foundation form. Finally, the 15m PHC400-AB100-C80 pile was chosen as the foundation of high building. Pile square layout with a
spacing of 1.5m*1.5m, and the bearing capacity characteristic value is 1200kN. A total of 1897 piles was used in the foundation.

3. Difficulties during constructing
According to the construction sequence, construction technical difficulties were mainly as follows.

3.1 End pressure
The bearing capacity of single pile was designed as 1200kN, according to the relevant norms, its limit bearing force could not be less than 2400kN. For the different sandy soil ground, there was large difference between pile termination limit pressure and pile bearing capacity [4,5]. After a fully negotiation that all parties involved in, the end pressure was preliminarily determined as 3000kN, and the type of pile pressing machine was YZY-360.

3.2 Pre-hole parameters
There was not access to relevant engineering examples. According to the engineering characteristics of sand, guiding hole parameters of this project were identified as: diameter 360mm, depth 17.5m (net of 4m hollow pile, reserved 1.5m undisturbed sand), hole guiding equipment was a walking-type spiral drill. After a series of field tests, the guide hole depth was adjusted to 18m.

3.3 Hole collapse
Avoiding hole collapses was the key of pre-stress high-strength concrete pile construction. Bentonite slurry was used in this project, with a proportion not less than 1.15, and the mud was Injected into the pre draft hole with a pressure of 0.6MPa. After removed 1m surface soil and ground leveling, brick slag of 300mm was laid on the construction field to ensure the construction quality and safety.

4. Construction process
The construction sequence was pushing one pile every three, and advancing from one side to the other side of buildings, so as to weaken the impact of driving pile on pre-guiding hole (Figure.1).

Figure.1 Sketch of pre-stress high-strength concrete pile construction
4.1 Pile test
Eight testing piles were pressed into sand on the external side of building field, and ten days later, low strain test and static load test were exerted on these testing piles (Table 1). The phenomenon of hole collapse was serious, the effective length of 01# pile was only 7.7m, and the effective length of 02#, 03#, 05# pile was longer than the depth of pre guide hole. After a sufficient negotiation, project participants drew the following summary suggestions that guiding pile foundation construction.

- Pre hole depth adjusted to 13.5m;
- Took terminating pressure as the control index, and the effective length as a reference index.
- Another pile should be added if one effective length of pile was less than 11m;
- Static load test preferred piles that effective length close to 11m.

4.2 Construction
A total of 1933 piles were pushed into sand ground by two pile pressing machine in two months (including 36 piles plus). Although affected by many external factors, the construction process smoothly, and the project was completed on time.

Table 1 parameters and test results of test pile

| Test pile number | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 |
|------------------|----|----|----|----|----|----|----|----|
| Designing length(m) | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| The final pressure(kN) | 3000 | | | | | | |
| Pre hole depth(m) | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 |
| Effective length(m) | 7.7 | 14.5 | 14.1 | 13.1 | 14.6 | 11.2 | 12.4 | 11.9 |
| Quality evaluation | Complete | Complete | Crackle(2.0m) | Complete | | | | |
| Test load(kN) | | | | | | | | 2400 |
| Max settlement(mm) | 11.63 | 9.52 | 8.00 | 10.25 | 8.95 | 10.41 | 7.88 | |
| Residual settlement(mm) | 2.27 | 2.19 | 1.23 | 1.83 | 1.32 | 2.05 | 1.93 | |
| Rebound rate | 80.5% | 77.0% | 84.6% | 82.1% | 85.3% | 80.3% | 75.5% | |

5. Quality testing

5.1 Processing inspection
The quality control of construction process was mainly focused on the following aspects:

- Pile acceptance on site;
- Monitoring of pile position;
- Pile pressing force monitoring;
- Statistics of pile effective length.

5.2 Completion and acceptance
Low strain reflected wave method was used to test pile quality, and results according to Chinese Regulations showed that class I pile accounted for about 80%, class II pile accounted for about 20%, no class III or IV pile. Results of static load test all met the design requirements (Figure 2).

6. Conclusion
Engineering practice and theoretical research are few in pressing pile into complicated soil, especially into sand. According to engineering practice, this project has obtained some satisfying results, and met the engineering demands. There are some aspects such as collapse, end pressure, pre-hole parameters needed to be further studied.
It was relatively difficult to press pipe pile statically into complicated ground. With mud of large proportion protecting holes, pushing piles into Pre-cited hole in sandy ground was introduced in this assay, and the requirement of engineering demands were fully met after a strict on-site test, which could be a worthy reference for the similar projects.

Acknowledgement:
Thanks for the support of the Doctoral Fund of Shanghai Urban Construction Vocational College

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