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Review Article

Evaluation of Dynamic Driving and Hydraulic Static Pressing Methods for PHC Pile Installation in High-Salinity Sabkha Soils at Ras Al-Khair, Saudi Arabia

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Abstract

Prestressed High-Strength Concrete (PHC) piles have recently been utilized in Saudi Arabia for the Ras Al-Khair Steel Plate Manufacturing Project due to their high structural capacity, durability, and rapid installation. This study evaluates the performance of PHC piles installed using two construction methods: dynamic driving and hydraulic static pressing. The performance of the installation methods was assessed based on the results of axial compression load tests, with a maximum allowable settlement of 25 mm under the highest test load. The static pressing method results on a lower average settlement and narrower range of settlement readings for the tested piles, which suggest that it is more reliable than dynamic driving method.

Keywords: Prestressed High-Strength Concrete (PHC) Piles, Pile Installation, Dynamic Driving, Hydraulic Static Pressing, Axial Compression Load Test.

1. INTRODUCTION

Prestressed High-Strength Concrete (PHC) piles are widely used because of their high strength, durability, load-carrying capacity and rapid installation. Their application has expanded to the Middle East, including Saudi Arabia [1], for the Steel Plate Manufacturing Project, where the technology has been piloted and is planned to be utilized in future for approximately 6,700 piles at the facility site. The performance of PHC piles depends on the correct pile design, installation method, and shaft friction between the pile and the surrounding soil.

The two commonly used installation methods are dynamic driving and hydraulic static pressing. Dynamic driving uses an impact hammer to drive the pile to the required penetration depth. Although this method provides high installation productivity, it generates vibration, noise, and soil disturbance that may affect pile-soil interaction. Hydraulic static pressing installs the pile by applying a continuous hydraulic force, resulting in minimal vibration and reduced disturbance to the surrounding soil. Therefore, this method may be preferrable in areas where control of vibration, noise and ground disturbance is required.

This study compares the performance of the dynamically driven and hydraulically pressed PHC piles installed at the Ras Al-Khair Steel Plate Manufacturing Project in Saudi Arabia. The comparison is based on the results of axial compression load test, with a maximum allowable settlement of 25 mm under the highest test load. The study also complements previous investigations of wick-drain ground improvement and PHC pile performance conducted at the same site [1, 2]. The implementation of wick-drain technology at the project site for soil treatment enhances the interaction between the pile surface and the adjacent soil in the Sabkha area, resulting in improved shaft bearing and end bearing capacities of the piles. Other ground improvement methods, such as Dynamic Compaction (DC) and Rapid Impact Compaction (RIC), were utilized in areas empty of Sabkha; however, no piles have been installed or tested in these locations.

The Steel Plate Manufacturing Project is located in an area characterized by extensive sabkha soils, loose to very loose sandy soils, high soil salinity and high groundwater table, which present challenges for foundation selection and installation techniques. Recent research [2] investigated the use of prefabricated vertical wick drains with surcharge loading to improve sabkha soils at the Ras Al Khair Steel Plate Manufacturing Project. The study reported accelerated soil consolidation, faster pore water dissipation, reduced settlement, and improved ground stability, demonstrating that wick drains is an effective ground improvement technique for sabkha areas.

Previous research evaluates the performance of Prestressed High-Strength Concrete (PHC) piles at the Ras Al Khair Steel Plate Manufacturing Project [1]. Tests results prove that these piles exhibit adequate bearing capacity, limited settlement, minimal pile damage, and efficient installation. These results indicate that PHC piles can provide a reliable and economical solution for deep foundation for industrial projects under the ground conditions encountered at the project site.

Static axial compression load testing was conducted in accordance to ASTM D1143, Standard Test Method for Deep Foundations Under Static Axial Compressive Load [3]. Axial tension load testing was conducted in accordance to ASTM D3689, Standard Test Method for Deep Foundations Under Axial Tension Load [4].

2. Field Test Data

A total of 21 PHC piles were installed at the project site, consisting of 17 dynamic-driven piles and 4 hydraulically pressed piles. 14 of the dynamic-driven piles were subjected to static axial compression load tests, while 3 were subjected to axial tension load test. All 4 hydraulically pressed piles were subjected to static axial compression load tests.

Of the 14 dynamic driven piles tested using axial compression load tests, 10 piles satisfied the acceptance criteria, while 4 piles exceeded the allowable settlement limit. The measured settlements ranged from 7.55 mm to 66.51 mm, with an average settlement of 23.35 mm. The acceptance rate for the dynamically driven piles subjected to load testing was 71.43% (10 out of 14 piles). Although the majority of the tested piles satisfied the acceptance criteria, the results showed large variation in piles settlements measurements.

The three (3) dynamic driven piles subjected to axial tension load test satisfied the project requirements, resulting in100% pass rate for the tension load test.

Three (3) hydraulically pressed piles satisfied the project acceptance criteria, corresponding to an acceptance rate of 75%, while 1 pile recorded a settlement of 29.32 mm, exceeding the allowable limit of 25mm by 4.32 mm. The measured settlements range from 10.49 mm to 29.32 mm, with an average settlement of 16.70 mm.

Installation Method	Test Type	Number of Tests	Pass	Fail	Pass Rate
Dynamic Driven	Axial Compression	14	10	4	71.43%
Dynamic Driven	Axial Tension	3	3	0	100%
Static Pressing (SP)	Axial Compression	4	3	1	75.00%
Total	**All Tests**	**21**	**16**	**5**	**76.20%**

Overall, 16 out of 21 piles satisfied the project requirements, resulting on an overall acceptance rate of 76.2%.

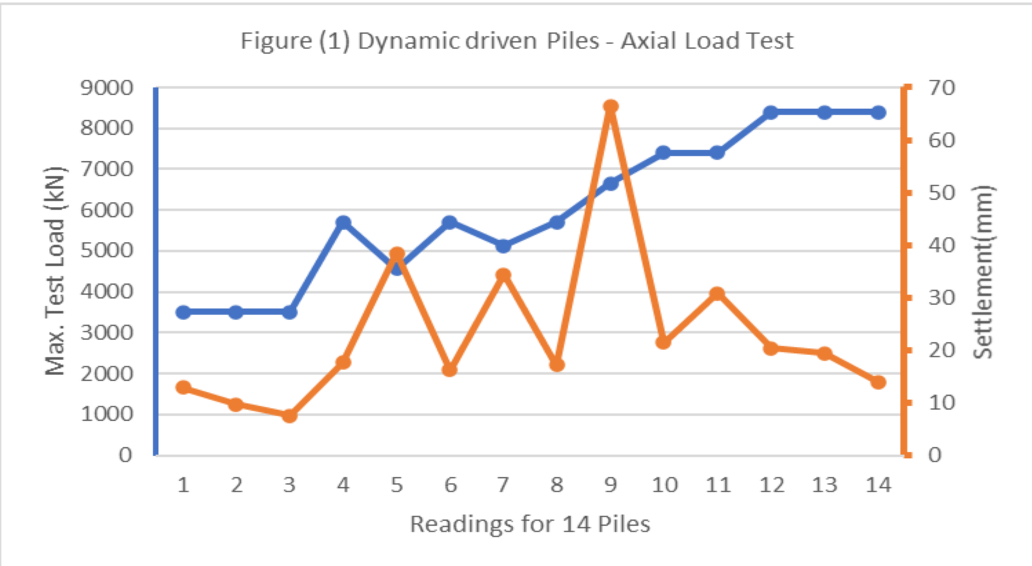

Figure 1: Axial compression load test result for dynamically driven piles

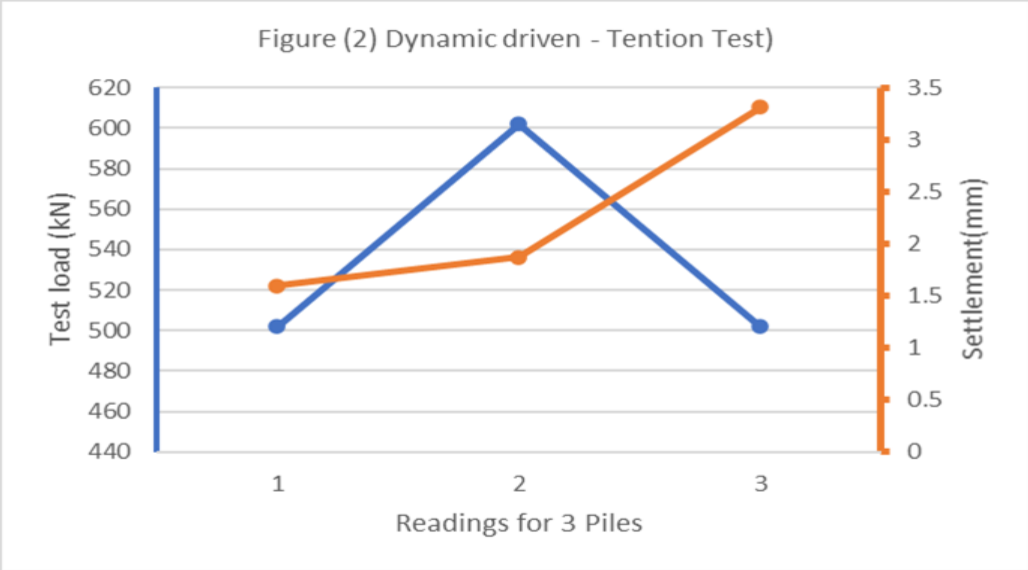

Figure 2: Axial tension load test result for dynamically driven piles

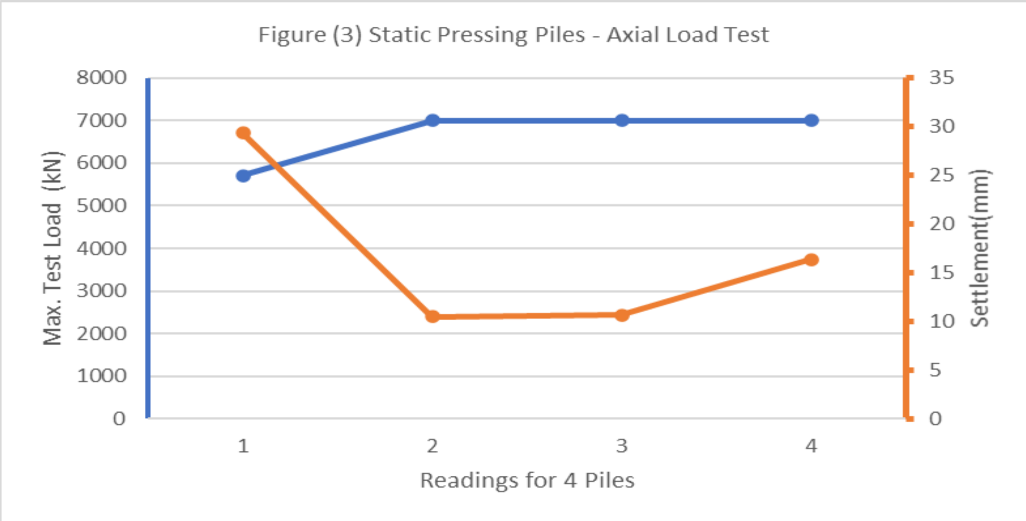

Figure 3: Axial compression load test result for hydraulically pressed piles

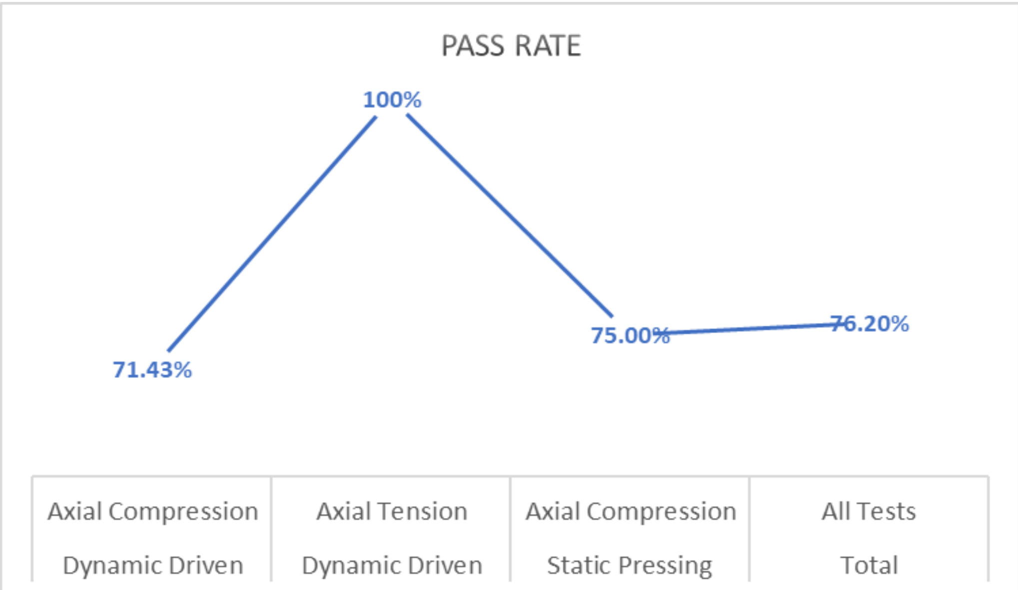

Figure 4: PHC Piles tests and pass rates

3. Comparison of Installation Methods

The settlement results from the axial compression load tests showed differences in performance between dynamic-driven and hydraulic pressed PHC piles.

The dynamically driving piles have a settlement range of 7.55 to 66.51 mm and an average settlement of 23.35 mm. 10 out of 14 piles pass the axial compression load test while 4 piles fail, resulting in 71.42% acceptance rate. In comparison, the hydraulically pressing PHC piles, have settlement range between 10.49 and 29.32 mm with an average settlement of 16.70 mm. 3 out of 4 piles passed the axial compression tests, while 1 pile fails resulting of 75% pass rate.

The larger variations on the settlement reading range observed for the dynamic-driven piles could potentially be correlated to the differences in the hammer energy, defective pile cushion, pile misalignment, and the deviation in ground conditions.

Hydraulically static pressing method reduces the vibration and ground disturbance compared with dynamically driving method. In this project, it resulted in a lower average settlement and a narrower settlement range, demonstrating more uniform performance. However, the number of hydraulically pressed piles was limited to 4, which should be increased to strength this study's outcome for future.

Parameter	Dynamic-Driven Axial Test	Dynamic-Driven Tension Test	Static Pressing Axial Test
Number of Tests	14	3	4
Average Settlement	23.35 mm	2.26	16.7 mm
Maximum Settlement	66.51 mm	3.31	29.32 mm
Minimum Settlement	7.55 mm	1.60	10.49 mm

Moreover, precise comparison between these two methods from cost and productivity aspects is difficult because it depends on pile specifications, soil conditions, and constraints related to vibration, noise, and soil disturbance. However, [5] reported that hydraulic pressing has higher initial equipment costs than dynamic driven pile. In terms of productivity, [6] indicated that dynamic driving is faster than hydraulic pressing, with installation rates of approximately 0.5 - 1 m/min and 0.1 – 0.3 m/min, respectively.

For the Steel Plate Manufacturing Project, which is located in an open area, dynamic driving method may be more economical and productive. However, the vibrations it generates may disturb the soil and affect the success of the installed piles. Hydraulic pressing, although is costlier and slower, offers the advantages of reduced noise, vibration, and soil disturbance. Therefore, the final selection shall consider the overall technical, economic, environmental, and project requirements.

4. CONCLUSIONS

A total of 21 PHC piles were installed and evaluated at the Ras Al-Khair Steel Plate Manufacturing Project.

Dynamically driven piles underwent axial compression load tests, achieving an acceptance rate of 71.43%. All dynamically driven piles subjected to axial tension load satisfied the project specifications. Hydraulically pressed piles also underwent axial compression load tests, with an acceptance rate of 75.00%. In total, the acceptance rate for all tested piles was 76.2%.

The hydraulically pressed piles exhibited a lower average settlement and a narrower range of settlement readings compared to the dynamically driven piles, which displayed a broader settlement range. These findings suggest that hydraulically pressed piles perform better in terms of settlement under the ground conditions present at the project site. However, this conclusion is drawn from a limited number of hydraulically pressed piles tested.

Furthermore, the factors contributing to the increased variability in settlement readings for the dynamically driving piles were not quantified in this study. It is recommended that further testing with a larger number of piles be conducted to more accurately evaluate and compare between the performances of the two installation methods.

Moreover, the effectiveness of the two installation methods will need to be further investigated with PHC piles installed and tested in the dynamic compaction and rapid impact compaction (RIC) zones, to understand the influence of the selected soil treatment technology on pile performance.

In summary, the test results indicate that both dynamic driving and hydraulic static pressing are effective methods for PHC pile installation under the project site conditions. However, hydraulic static pressing method appears to offer a potential advantage regarding settlement consistency.

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