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Full-scale tests on laterally loaded helical steel piles in dense sand

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ABSTRACT: Helical Steel Piles (HSP) are increasingly used to support critical infrastructure, such as rail and road networks, power grids, and solar farms. In certain applications, they need to withstand lateral loading. Experimental data on the lateral behaviour of HSPs is scarce, which limits the development of design approaches. This paper addresses this gap presenting an experimental series of full-scale HSP tests under monotonic and cyclic lateral loading. It is shown that an additional helix close to the pile head increases lateral pile stiffness and bearing capacity. The static and cyclic experimental data will support the validation of numerical and analytical models for laterally loaded HSPs.

1 INTRODUCTION

Helical steel piles (HSPs) are a suitable solution for supporting critical infrastructure such as power grids and solar farms. In certain applications HSPs are subjected to lateral loading. Although experimental data on their lateral behaviour is crucial for developing design methods, such data remains scarce. Within the framework of the GEOLAB project, full-scale tests on HSPs were performed using a novel experimental setup in the Geotechnical Test Pit at the TU Darmstadt. These tests aim to support the development of robust and reliable design methods for laterally loaded HSPs and thereby promote the use of HSPs in critical infrastructure.

2 METHODS

An experimental campaign was carried out on ten HSPs with shaft outer diameter, D_o =60.3 mm and wall thickness, t=7.1 mm, with six different configurations varying the diameter (157 mm and 239 mm), position, and number of helices (Figure 1). Prior to pile installation, dry Darmstadt sand was placed in a test pit measuring 5.45 m x 5.00 m. The sand was compacted in 14 layers using a vibratory plate in two passes per layer, forming a 2.82 m-deep bed of very dense sand ($D_r \approx 88\%$).

All ten HSPs were installed using a hand-held torque motor under its own self-weight (approx. 0.25 kN), with a minimum spacing of 1.5 m between piles and 0.75–1.0 m to the pit boundaries. The embedment depth of the HSPs was about 1.4 m. After installation, a sand plug of 20–30 cm was observed inside each pile.

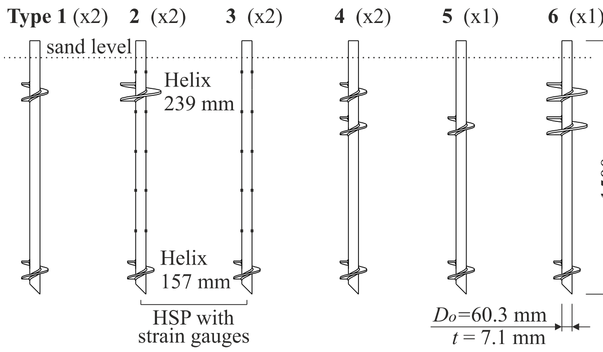

Figure 1. HSP configurations investigated in the study.

The pile heads were equipped with an aluminium box fitted with glass plates, allowing the installation of nine displacement transducers, three along each of the X, Y and Z axes, to enable precise three-dimensional tracking of the loading point. Two piles were instrumented with five pairs of strain gauges along the shaft, and temperature sensors.

The applied horizontal force was measured using a 20 kN load cell. The hydraulic actuator was controlled via embedded displacement and load sensors.

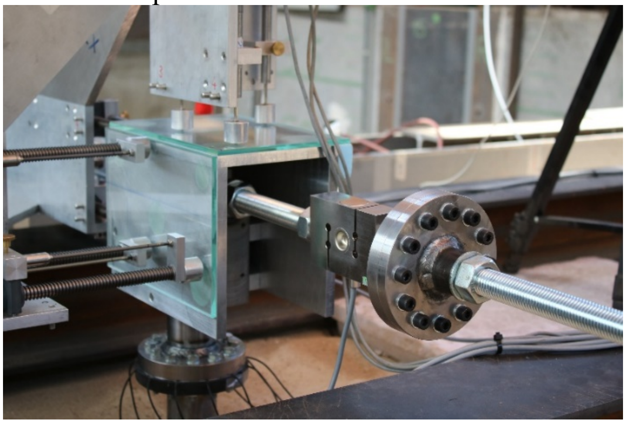

Figure 2. Loading rig with a load cell and nine displacement transducers (three along each of the X, Y and Z axes).

3 TESTING PROGRAMME

Each HSP was initially subjected to monotonic loading in displacement-controlled mode with a rate of 2 mm/min. Upon reaching a predefined maximum load, estimated to prevent steel yielding, the load was kept constant for 20 minutes in force-controlled mode. Unloading was carried out in displacement-controlled mode, followed by maintaining a constant force of 0.1 kN for 20 minutes. Subsequently, a cyclic loading test was performed consisting of two or three packages of 1,000 cycles each (depending on the HSP type), with varying mean loads and load amplitudes.

4 PRELIMINARY RESULTS

Figure 3 compares the lateral load-displacement response for HSP types 2 and 3, evaluated at the loading point during the monotonic test. The results show that the additional helix close to ground surface in HSP type 2 significantly increases the stiffness of the lateral load-displacement response compared to HSP type 3, which lacks this additional helix.

Figure 4 shows the monotonic and cyclic response of HSP type 3. Three packages of 1,000 cycles were applied, with increasing mean load and load amplitude. Greater deformation accumulation was observed at higher mean load levels and larger load amplitudes. As the number of cycles increased, the rate of deformation accumulation decreased, while the stiffness of the response increased.

5 CONCLUSIONS

A novel experimental setup in the Geotechnical Test Pit of the TU Darmstadt proved effective for conducting both monotonic and cyclic lateral loading tests on helical screw piles in dense sand. The results show that additional helices close to the ground surface led to a stiffer load-displacement response. Further technical and economic analyses are required to assess the practical feasibility of the adjustments to the HSPs examined in this study. The resulting dataset is available in an open-access repository and will be used to validate numerical and analytical models (Bourne-Webb et al., 2025).

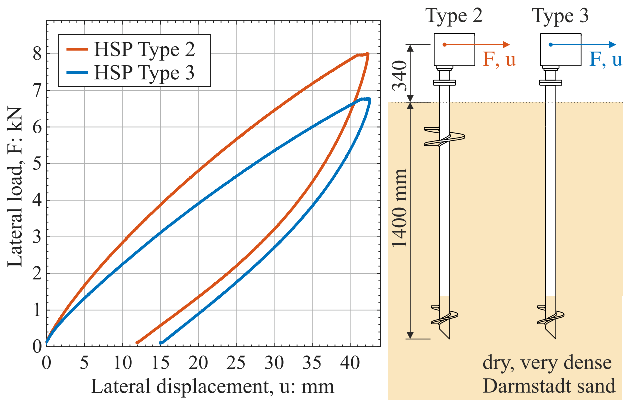

Figure 3. Comparison of the lateral load-displacement response for HSP types 2 and 3.

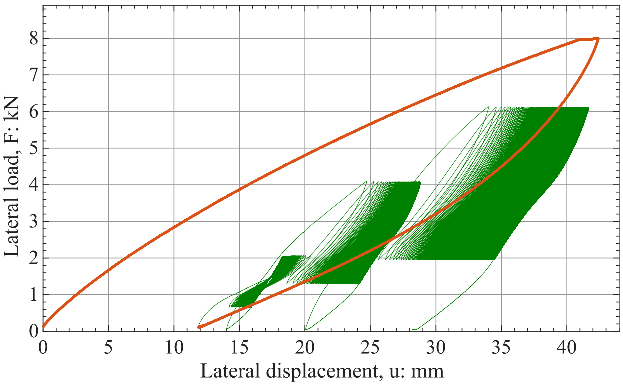

Figure 4. Lateral load-displacement response for HSP type 2, monotonic loading (red) and cyclic loading in three packages of 1,000 cycles each (green).

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REFERENCES

Bourne-Webb, P., Bodas Freitas, T., Georgiadis, K., et al. (2025). *GEOLAB - Transnational Access Project HELITEST: Testing and Advanced Modelling of Helical Steel Piles for Support & Recovery of Critical Infrastructure* [Data set]. Zenodo. https://doi.org/10.5281/zenodo.15495048