Axial pile testing in very dense sand

Interpreting pile load tests to develop a safe and sustainable design procedure

Kevin Duffy

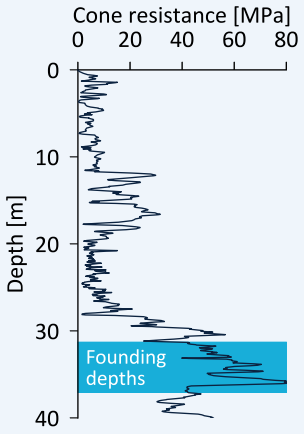
Project background & description

Three test sites on full-scale piles have been established in the Netherlands as part of the **Improved Axial Capacity of Piles in Sand project (InPAD)**. The first of these sites at the Maasvlakte consisted of three driven precast (L ≈ 31m; 400mm square), four driven cast-in-situ (DCIS; L ≈ 33m; 380/480mm dia.) and four screw injection (SI; L ≈ 33m; 610/850mm dia.) piles. All piles were loaded stepwise to failure.

Factors influencing the monitoring project design

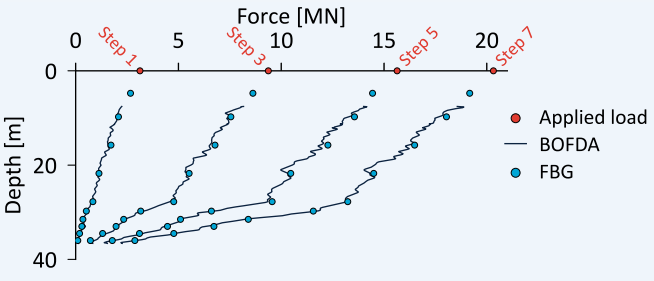
The subsurface conditions at the Maasvlakte are unique with the piles founded in a layer with **cone resistances up to 80 MPa**. Consequently, installation conditions were harsh and necessitated a resilient instrumentation and testing system.

A special load test frame was designed to reach **failure loads of up to 25 MN**. Up to twelve grout anchors in this frame provided the reaction force for the pile. Inclination of the frame and deformation of the anchors was measured continuously during the load test.



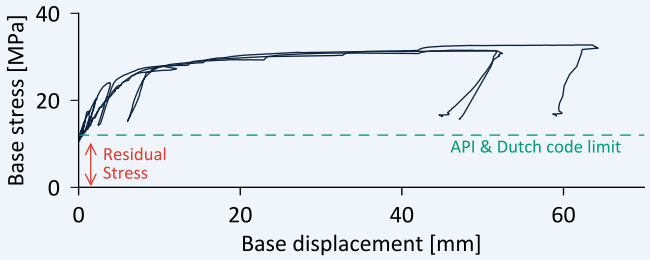
Scope of the instrumentation used

All piles were **instrumented across their entire length with two different fibre optic sensors**, one giving distributed force distribution profiles (BOFDA) and the other discrete data (FBG). The applied load and resulting displacement at the pile head was monitored during each load test.

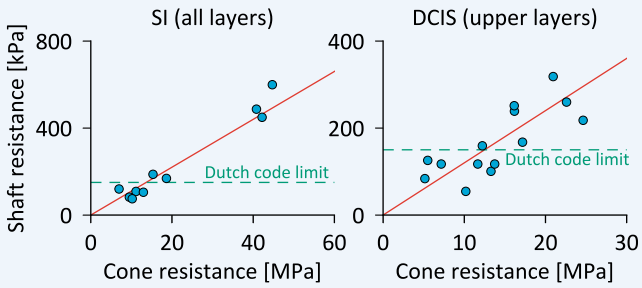


Sample of test results

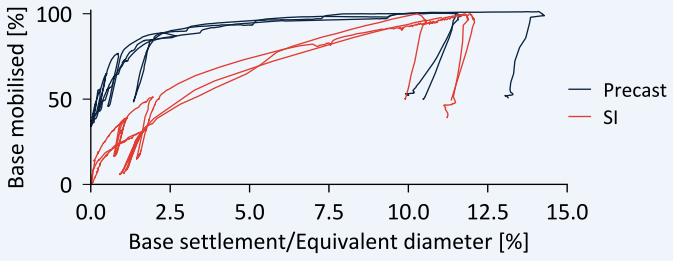
Very high residual loads were generated along the pile base and pile shaft in the three driven precast piles after the installation process. Correspondingly, the base resistances mobilised during the pile tests **were well in excess of the limiting resistances**, such as those proposed in the Dutch and API design codes (=12-15 MPa).



Constant shear stresses with depth were measured for the DCIS and SI, **also in excess of their respective limiting resistances**.



Mobilisation of the base resistance **of the SI piles was much softer compared to the precast piles**, indicating the SI piles are more of a soil-replacing pile than soil displacing pile.



Most significant information derived

- Measured base and shaft resistances **exceeded the limiting design resistances** specified in pile design standards.
- **Very high residual stresses generated** in the driven pre-cast piles.
- **New design factors** for the base and shaft resistance of driven precast, screw injection and driven cast-in-situ piles.
- An economical and sustainable design solution could be obtained for quay wall design in the Maasvlakte, potentially **saving 3.3 kilotons of CO_2** per kilometre of quay wall.