# CASE STUDIES

## SESSION LEAD RODRIAAN SPRUIT AND SAM PAIKOWSKY

Presented papers:

### Influence of displacement piles on surrounding soil and nearby piles: a case study. Presented by : H. Tuenter

**ABSTRACT**

For a large construction project in the greater Zug area (Switzerland), four maintained load axial pile loading test were performed on 600 und 700 mm diameter, 45 m long full displacement piles. The maximum test load was around 7800 kN. All test pile rebar cages were fitted with fiber-optic distributed sensing temperature and strain sensors, allowing thermal integrity profiling of the test piles and the measurement of residual load. Because of the large pile diameter and nearby sensitive infrastructure, pile installation was accompanied by a comprehensive monitoring of free field soil displacement and heave. Pile installation monitoring comprised ten purpose built push in soil extensometers to measure vertical soil heave at various depths, total station measurements and precision levelling for measuring surface displacement and heave, and measurement of excess pore water pressures during installation. The results of heave and lateral displacements are accordingly calculated by Cavity Expansion (CE) and Shallow Strain Path Method (SSPM) and modifying factors are recommended to improve predictions with SSPM that can take into account soil compressibility for non-homogeneous, layered soils.

### Ultimate bearing capacity of MV piles derived from load tests, a suggested new design approach. Presented by : R. Spruit

**ABSTRACT**

Driven steel beams with grout injection (MV-piles) are since the 80’s in use in the Rotterdam harbour to deliver tension bearing capacity for anchoring large deep-sea quay walls. This paper discusses the results from pile load tests on two sites within a historical context of port development and evolving load tests. The tested tension piles were fully instrumented with fiber optic strain sensors allowing for capturing a continuous strain profile along the full length of the piles. Practical information on instrumentation, testing and interpretation will be illustrated with actual test results.

### Quantitatively assessing the geometry and base conditions of drilled shaft excavations. Presented by : B. White

**ABSTRACT**

Drilled shafts are common foundation elements used for structural support all around the world. The quality of construction of a drilled shaft is critical due the large structural loads and often limited redundancy of many drilled shaft foundations. Many design codes allow for consideration of end bearing in the design, and assume certain conditions at the bottom of the foundation. For shafts designed to resist loads using end bearing, the shaft bottom condition is of particular interest. Some current methods to evaluate the shaft bottom condition are to send an inspector to the bottom of a dry excavation or to retrieve video of the shaft bottom using specialized equipment. Clearly, sending a person to the bottom of an excavation is not desirable from a safety standpoint. A video of the bottom of the shaft may provide a visual interpretation of the condition of the soil/rock at the base of the shaft, but provides no clear debris/sediment thickness or quantitative measurements of material strength. Recently, test equipment and evaluation methods have been developed to safely collect measurements at the bottom of a drilled shaft and evaluate debris thickness and competency of the bearing material. The Shaft Quantitative Inspection Device (SQUID) is a downhole device that collects force and displacement measurements as load is applied and the shaft bottom material is penetrated. Three individual measurements of force and displacement are collected simultaneously, and viewed in real time during testing. The resultant force-displacement curves are evaluated for debris/sediment thickness as well as soil/rock strength. Foundation excavation geometry and verticality are of interest to be sure the structure load is transmitted axially down the foundation element and no unexpected moments are introduced into the foundation. In addition, if unexpected drilling or ground conditions are encountered, measurement of the geometry of the excavation can identify areas of concern and lead to proper corrective procedures. Current industry methods for measuring shaft verticality include physical measurement or sonic measurements at chosen intervals. Often these methods require mobilization of additional equipment to complete the measurement and can be time consuming. The SHaft Area Profile Evaluator (SHAPE) is a downhole device that collects sonic measurements of the shaft geometry every 1 second in 8 directions simultaneously. The results are downloaded shortly after data collection and automatically processed to provide a near immediate rendering of the shaft geometry and verticality. The SHAPE can be deployed using the drill rig or a winch system and data is typically collected at a rate of 1 linear foot per second. SHAPE systems are available for measurements in any type of drilling fluid or in dry conditions. The SQUID and SHAPE have been used on many projects over the last several years for evaluation of shaft quality of construction. This paper will present general test results as well as cases where interesting data were observed. In addition, suggestions for best practice when testing and proper implementation of specifying the SQUID and SHAPE equipment and test methods will be provided.

## Steel piles driven with Follower in Glacial Till and Chalk. Presented by : A. Crochelet

**ABSTRACT**

Offshore, pile driving monitoring (PDM) is a well recognised practice which can be employed to control driving behaviour and determine pile bearing capacity. The use of an instrumented follower to perform pile driving monitoring and pile testing activities is less common due to the higher complexity of signal interpretation. However, PDM presents advantages in terms of cost optimisation during construction and testing activity, particularly in cases where the piles are driven below water and validation is needed for a large amount of piles.

This paper aims to present the testing procedure, the main field observations during pile driving activities and some examples of the interpretation of signals recorded during driving, of a vast pile driving campaign carried out on hollow cylindric piles of 0.61m OD and length variable between 14m and 22m. These piles were mainly driven in glacial till deposits overcoming chalk.

A follower was used to drive the piles to target penetration with the aim of avoiding the use of an under-water hammer and sensors. This mobile add-on pile section was designed to allow operations in a water depth of approximately 20m. On a pre-defined number of piles, strain gauges and accelerometers were installed on the external shaft of the “test piles”, and placed at two different levels respectively, at the top of the follower and the pile. This allowed the strains and accelerations to be measured at different levels, assessing energy losses between the pile and follower system. Signal matching analysis procedure at both instrumentation levels was used to define the follower and pile behaviour while driving. This allowed the use of the instrumentation at only the follower top for the majority of the other tested piles.Most of the piles were driven in glacial till deposits, and signal matching analyses performed at the end of continuous driving evidenced a high variability in space of the estimated static soil resistance to driving. Short and long-term restrikes were performed to estimate the long-term pile capacity, evidencing a relevant gain in terms of back-analysed static resistance only after a significant waiting period. In some locations, the pile tip was entering by 1/3 of the pile shaft within chalk deposit. On these piles, the long-term capacity was also estimated. Recorded signals after a short term restrike or driving interruption evidenced a fast evolution of the interface behaviour. An increase of pile bearing capacity is proven with long-term restrikes as well. This paper discusses the main findings of this pile driving testing campaign, with focus on the functionality of an instrumented follower to drive piles in shallow water. Understanding the hammer/follower/pile/soil system in detail enables to instrument the follower rather than the pile top and allows the validation of a large number of piles in both a cost and time effective way. Soil plug measurement was performed on all tested piles to check the global behaviour of the pile and soil while driving, and supporting hypotheses used for the signal matching analyses..

## Effect of preloading on soil setup effects of a soft clay through pile static and dynamic load tests. Presented by : Behroozian

**ABSTRACT**

Soil setup effect is a natural phenomenon where pile bearing capacity increases over time as a result of dissipation of excess pore water pressure as well as soil aging. Soil setup significantly contributes to the increase in shaft bearing capacity of prefabricated displacement piles installed in saturated clay. The past experiences indicate that shaft bearing capacity increases almost linearly with the logarithm of time elapsed after the pile initial drive, usually quantified using a dimensionless setup factor. The magnitude of setup factor is governed by pile geometry and type of surrounding soil. To quantify the setup rate potential, a minimum of two field measurements of the pile ultimate load are required. Whenever signal matching analyses are performed on pile dynamic load test results at end-of-drive and restrike data, the variations of setup effects along the pile shaft can be determined. The main objective of this paper is to evaluate the effects of over-consolidation ratio (OCR) on setup factor using pile dynamic load tests (DLT) at end of initial drive and restrike as well as static load tests (SLT). For this purpose, an elaborate field testing program was conducted at Bidboland II Gas Refinery site. The program consisted of DLT and SLT on the prestressed spun concrete piles that have been driven at different locations of the site having variations of OCR as a result of preloading under different surcharge pressures. Results indicate that shaft resistance has considerably increased over time at the study site. The setup factor is affected by the over-consolidation ratio in such a way that with increasing OCR, the setup potential has reduced. The findings of the study are useful in engineering applications of piling in clayey deposits in which the time constraints of construction does not allow performance of dynamic load tests at different time steps as well as estimating the setup factor at sites having over-consolidated soil.

## Pile dynamic versus static load tests in fine-grained deposits of Southwest Iran with special attention on soil setup effects. Presented by : Fakharian

**ABSTRACT**

Many precast driven piles have been constructed in soft soils of southwest Iran in Khuzestan Province in oil, gas, petrochemical and other industrial projects within the past 20 years. Estimating the adequate pile bearing capacity and drivable embedment depth of piles are always a major challenging task both during the design and construction phases. Clients have been promoted to carry out dynamic load test (DLT) and static load test (SLT) on both “test piles” and “construction piles” to optimize the pile design and improve the execution quality. Data sets of several projects with number of piles ranging from 5000 to 8000 in each project are compiled for comparison purposes of the ultimate load obtained from DLT with SLT tests. The study area geological stratification is mostly comprised of soft cohesive layers on top underlain with medium stiff to stiff strata. Soil setup potential is understood to be considerable in the region. During the pile testing program, it has been attempted to carry out DLT at the end of drive as well as restrike at different time intervals up until few weeks or months. Then correlations for soil setup are used to determine the parameters of the study site such as “A” and t0 of Skov and Denvor relation. The results have shown that the t0 is very variable in the region ranging from 0.1 day in highly permeable strata up to 1 day in pure cohesive strata with low permeability. The results also indicate that if the DLT tests are corrected for setup effects equivalent to the SLT time past from the initial drive, more accurate agreements could reach. During piling operation, as it may not be feasible to wait for sufficiently long time for the setup to occur, and usually DLT tests are carried out within few days from pile installation, the extrapolated capacities considering site specific setup effects are used in verifying the design capacities. Considerable savings are made through the explained procedure both in “construction cost” and “construction time” of the projects.

## Lateral load testing and 3D stress measurements in a pile foundation. Presented by : A. Lemnitzer

**ABSTRACT**
Embedded sensors within infrastructure elements are powerful catalysts for new designs and construction methods, enabling advanced data collection and informed decision making. This paper presents the development, validation, and implementation of a prototype instrumentation tool utilized in large-scale lateral load tests of rock-socketed pile foundations, with the objective to measure shear stresses near the rock-soil boundary. The proposed instrumentation is novel in that it will be the first attempt to determine experimentally the 3D strain field through embedded sensors with immediate application to a broad array of pile foundation engineering problems. Data obtained from the prototype instrumentation is used to clarify whether shear force amplifications in piles crossing soils with strong stiffness contrasts are real, or an artifact of analytical, Winkler-based design methodologies. Three reinforced concrete pile specimens with a diameter of 0.46 m and a length of 4.9 m were subjected to reverse cyclic lateral loading up to complete structural failure. The sensors' development, design, and construction, as well as their performance in measuring shear stresses will be discussed by comparing experimental data with predictions from conventional software tools. Ultimately, this study aims to improve the design and construction of more practical, resilient, and economical infrastructure.

## Measuring Time Dependent Stress-Changes around a Driven Pipe Pile in Medium Dense Sand . Presented by : M. Kidane

**ABSTRACT**
Time dependent changes of pile capacity in sands are often attributed to a decrease of arching effects in the surrounding soil following pile driving. This effect is assumed to lead to a gradual increase of radial stresses acting on the pile shaft and thus on an increase in pile capacity. This time dependent increase is referred to as pile setup. As part of an R&D project of Germanys Federal Waterways Engineering and Research Institute (BAW) one open ended pipe pile was equipped with combined total stress and pore water pressure sensors in order to investigate effective stress changes over a measurement period of almost 5 years. Additionally, after 28 months, two pairs of strain transducers and accelerometers were installed at the pile head and toe for stress wave measurements during pile installation and re-driving. The pile was driven at a harbour site that is subject to tidal water level changes. The measurements revealed a decrease rather than an increase in radial stresses, all though the pile capacity increased over time following evaluation of the stress wave measurements.

## BAM Screw Piles 2.0: Validating Design for 'De Drie Hoefijzers' by Rapid Load testing. Presented by : J. Bakker

**ABSTRACT**
Following an amendment on the Dutch Construction Decree in 2016 design parameters for end bearing of pile foundations have been reduced by 30% on January 1st 2017. This amendment was motivated by research on load testing data of foundation piles, which showed an overestimation of end bearing and consequential compromised safety. The new situation potentially results in a considerable increase in installed lengths as well as cross-sectional areas, with possible executional, economic and environmental consequences. A piling contractor can deviate from the CPT-based design parameters by performing pile load testing. NPR7201:2017 offers the possibility to validate a preliminary design based on freely chosen (assumed) design parameters, by verifying suitability up to design load based test loads. BAM was awarded the installation of the foundation for housing development project 'De Drie Hoefijzers' in the central train station area in Breda. Because of the presence of sensitive objects in close proximity to the project area, a pile system with low vibration installation is selected. The BAM Screw Pile 2.0 is an optimization of the CFA pile, combining easy installation with minimal relaxation of the soil around the pile tip by introducing a permanent cast steel, serrated drill bit. Experiences with the BAM Screw Pile 2.0 thus far show considerably higher capacities compared to CPT-based design for standard CFA piles. Therefore it was decided to incorporate a pile testing program to corroborate this experience and optimize the design of the foundation. The pile load testing method selected was Rapid Load Testing (StatRapid system). Three test piles following the preliminary design with assumed higher design parameters (20 m in length with a diameter of 800 mm) were subjected to test loads ranging from 6.0 to 7.3 MN (design loads ranging from 2.8 to 3.1 MN). The piles did not exhibit soil mechanical failure and as a consequence the preliminary design was validated. Effectively the approach saved 1 km of pile length, reducing cost by €175.000, as well as a resulting reduction in CO2 production of 80 tons

## Case Study Bi-directional Loadtest Paris Bassin Austerlitz. Presented by : M. Profittlich

**ABSTRACT**
The bi-directional testing team of Fugro Foundation Testing (Loadtest) is often presented with interesting projects which are a little out of the ordinary. Be they geotechnical, logistic or just deemed to be extremely difficult to do, they always rise to the challenge. The project detailed in this case study is one such project. Originally, thought to be impossible to perform by traditional load testing means in which all the load is applied at the head of the foundation element, a solution was found using the bi-directional static load test method using Osterberg cell technology. The load test was a conventional O-cell bi-directional test in the way it was finally undertaken, but the application was certainly unusual.

## Comparison of predicted and measured pile driving processes at steel pipe piles in North and Baltic Sea. Presented by : Kortsch

**ABSTRACT**
Foundation types of offshore wind turbines are mainly realised with steel pipe piles whereas most commonly monopiles with large diameters or jacket piles are used. Against the background of cost effectiveness, the selection of a driving system as well as design fatigue calculations it is of major importance to run driveability analyses prior to the installation process. Essential criteria for that are the duration of a driving process and number of blows, pile driving stresses in compression and tension and soil resistance to driving (SRD). While the application of SRD models for impact driven piles in sand and clay is considered as well established a trusted prognosis of pile driving in other soils or materials like chalk or the prognosis of vibratory pile driving is still a challenge. At real pile driving usually dynamic pile driving monitoring is performed in order to record real blow counts and stresses in the pile and furthermore, to verify pile capacity. In this paper driveability analyses and SRD models are compared with results of dynamic pile tests and pile driving monitoring in selected offshore wind farm projects in the North and Baltic Seas in order to check their applicability. Measurements were taken during the pile driving of small and large diameter pipe piles in sand or chalk dominated soils by the use of impact and, partly, vibratory hammers. Using appropriate wave equation software (GRLWEAP) driving processes could be recalculated and compared to measured data and records of the driving system.

## Dynamic load test and rapid load test on two large diameter steel pipe piles with double crossed steel ribs inside the pile bottom section. Presented by : S. Lin

**ABSTRACT**
Tokyo International Cruise Terminal, a four-story passenger ship terminal, was constructed at the Tokyo Bay area in 2020. The terminal building is on the jacket-type pier foundation supported by large-diameter steel pipe piles (SPPs) having an outer diameter (Do) of 2 m. A very soft sediment exists below the seabed to a depth of about 35 m. The surface soft layer is underlain by a gravel layer of 4 m thick and a mudstone layer having SPT N-values greater than 50. In order to estimate an appropriate embedment length of SPP in the gravel layer or the mudstone layer, rapid load tests (RLTs) were carried out on two SPPs having a length of 57 m (Pile 1) or 62 m (Pile 2). For both SPPs, double crossed steel ribs (#-shaped ribs) were welded inside the piles along the bottom 5 m section. Both piles were instrumented with strain gages at 8 levels to obtain axial forces during RLTs. High plugging was observed in both piles

## Comparison of static load test and rapid load test on steel pipe piles in two sites. Presented by : S. Kamei

**ABSTRACT**
Two case studies of comparison of the static load test (SLT) and the rapid load test (RLT) on steel pipe piles (SPPs) are presented and discussed in this paper. The Hybridnamic device, a falling-mass type RLT device, was used in both two cases. In Case study 1, an SPP having an outer diameter of 800 mm and a length of 23.8 m was installed in a weathered rock ground using the down-the-hole hammer method (a percussion drilling method). In the RLTs, three accelerometers were attached to the pile at head, intermediate and tip levels. Unloading Point (ULP) Method was used to interpret the RLT signals. Static load-displacement curves derived from the RLTs using three different accelerations are compared with those from SLTs with the step load method and the continuous load method. An appropriate selection of is discussed, based on the measured results. In Case study 2, an SPP having an outer diameter of 1000 mm and a length of 15.5 m was installed in a sandstone having SPT N-values greater than 50 using a vibro-hammer together with water jetting. Acceleration at the pile head alone was measured in the RLT. Static load-displacement curve derived from the RLT with ULP was comparable with that obtained from the SLT.

## Behavior analysis of post grouted micropiles in clay soils from tension load test results.. Presented by : M. Challapa

**ABSTRACT**
The design of micropiles is carried out through semi - empirical equations developed from field tests and previous experiences. This design represents an approximation of the real soil - micropile behavior and generates uncertainty since the design involves the ultimate micropile bond strength which is selected as a function of the type of micropile and soil characteristics and presents a broad range of values leading to a wide range of micropile resistances for the same conditions. Therefore, the standards recommend verifying and determining the field capacity of the micropile designed by static load tests, which are real-scale tests that allow knowing the field behavior between the built micropile and the ground. In the present paper, the analysis of the behavior of three different type D post-grouted micropiles was carried out through the results of static tension load tests following the FHWA NHI-05-039 "Micropile Design and Construction" standard, the geotechnical characteristics of the area were considered in the verification of the design and with the results of the load tests an analysis of the acceptance criteria recommended in the aforementioned standard was performed.

## Pile Installation Effect on Mobilized Side Shear Resistance in Fraser River Deposits. Presented by : T. Dajani

**ABSTRACT**
The friction fatigue phenomenon correlates the effect of the installation method on the degradation of mobilized side shear resistance, with vibro-hammers having been observed to result in further degradation of the side shear resistance in comparison with impact and jacked installation methods as reported by White (2005). In the Lower Mainland of British Columbia, Canada, nearshore structures constructed along the Fraser River are generally supported on open-ended pipe piles that are either partially or fully installed using vibro-hammers. This paper will review the results of high-strain dynamic testing on open-ended pipe piles installed in the Fraser River sediments to assess the effect of the installation method on the predicted mobilized side shear resistance.