OFFSHORE AND RENEWABLES

SESSION LEAD KEN GAVIN (TUDELFT) / SYLVIE RAYMACKERS (DEME)

Presented papers:

Numerical FE-based approach to identify the axial bearing capacity of piles.   Presented by : E. Heins

ABSTRACT

Piles are commonly used foundation structures. The installation process of piles is governed by dynamic processes which induce stress waves into the pile and the surrounding soil. Hence, the bearing capacity of the installed piles is influenced by the dynamic behavior and the resulting pile-soil interaction. To predict realistic bearing capacities, it is important to establish a thorough understanding of the underlying processes. Based on an understanding of both pile design and installation of offshore piles it is possible to identify the main influencing factors of dynamic load tests and to derive as well as to validate a new evaluation method for dynamic load tests. Another application that focuses on the dynamic pile behavior is the pile driving analysis. The impact of (unexpected) obstacles such as boulders in the ground represents a critical design consideration for pile driving. An approach to evaluate the pile behavior when impacting boulders during driving by applying one-dimensional wave theory is described. The example also empha-sizes the limitations of using one-dimensional wave theory to evaluate the pile-soil interaction and provides an alter-native outlook based on the proposed evaluation method for dynamic load tests.

Investigating vibro-driven monopile installation into sand in a geotechnical centrifuge.   Presented by : J. Mazutti

ABSTRACT

Bottom-fixed foundations currently dominate the offshore wind market. The installation of monopiles for offshore wind turbines by vibration is a promising alternative to the conventional impact-driven technique. Despite being a low-noise, time-efficient and cost-effective alternative, take-up of this method has been slow because uncertainties remain on the pile drivability and post-installation performance of vibro-installed monopiles, which translates to risk for the industry. Carrying out real scale field tests to increase understanding is extremely expensive and time-consuming. In contrast, centrifuge model tests are an alternative for investigating the impact of vibro-installation on the post-installation performance of monopiles for different soil conditions. The paper presents the development and first use of a mini vibro-driver in a geotechnical centrifuge. It highlights the importance of performing tests in such a way as to appropriately replicate soil mechanisms during vibro-driving. Finally, results from an initial pile installation test in the centrifuge are presented.

Pile Installation Optimisation in Calcareous Clays.   Presented by : Z. Delimi

ABSTRACT

Through the later years, the authors have been involved with pile driveability predictions, installation and dynamic monitoring of driven open-ended steel piles installed in the Arabian Gulf. This experience has been gathered into a database containing over 150 back-calculated offshore pile installation records and that is continuously updated with new inputs. It includes numerous pile installation in slightly over consolidated calcareous clays. Based on selected extracts from this database, a new and improved guidance to better characterize calcareous clays is proposed in this paper to provide an optimized and site-specific pile installation prediction. The developed guidance was used to optimize installation of new pile foundations of platform X installed in calcareous Clays. This paper also elaborates how the use of the Dynamic Monitoring System (DMS) and Signal matching analyses from past experience helps to develop a site-specific approach and minimize uncertainties related to Soil Resistance to Driving, set-up effect and soil dynamic parameters.

Numerical simulation of the vibratory and impact installation of monopiles in saturated sand.   Presented by : H. Eiesland

ABSTRACT

Offshore monopile installation by vibratory driving is proposed to have numerous operational and environmental advantages over traditional impact driving. That said, the uptake of this method has been rare, namely due to uncertainties related to pile bearing capacity after installation. This paper explores the numerical simulation of the soil response for a small portion of both vibro- and impact installation phases. Results indicate that for the same penetration depth achieved, the final stress state for both methods is similar. This may suggest that bearing capacity is also quite similar. In addition, the effect of different vibratory driving parameters and initial soil void ratio are also examined.

Designing PULSE and BLUE blow generators for experimental research in the geotechnical centrifuge. Presented by : T. Quinten

ABSTRACT

The next generation of monopiles for the offshore wind market will exceed 12 m in diameter. These foundations will facilitate the transition of bottom-founded offshore wind mills into deeper waters as well as enable the installation of larger turbines. There are questions whether conventional dynamic installation techniques can be used to install these foundations, mainly due to challenges related to sound emissions and fatigue. New dynamic installation equipment, that rely on the prolongation of the impulse duration, are therefore under development. PULSE and BLUE technology, both developed by IQIP, are examples of such equipment. Both strive to reliably drive large monopiles while drastically reducing sound emissions and fatigue manifestation. However, little is known about the practical implications of impulse prolongation of pile-soil-water interaction, which plays a critical role during installation. To study this, Delft University of Technology (DUT) is developing the hardware required to simulate the installation of monopiles with PULSE and BLUE technology in the centrifuge. By fitting a 16.4 mm syntethic polymer buffer between the hammer and the anvil, PULSE-blow characteristics can be replicated. The resulting system can be installed by DUT's miniature electro-mechanical pile driver. To simulate a BLUE-blow, the anvil is fitted with a stiff linear spring. For installation a dedicated actuator used which is currently under development. Both designs are verified by means of numerical simulation.

Impact and vibratory driven pipe piles: the difference in soil stresses and bearing capacities due to the installation method. Presented by : J. Fischer

ABSTRACT

The influence of the installation of open-ended pipe piles on soil stresses is studied by means of scale model tests in sand. Variants with different pile diameters, soil densities and installation methods are investigated. Measurements of pile dynamics and soil stresses are carried out as a basis for further analysis. During impact pile driving, the radial soil stresses acting on the pile wall increases to a peak value as the pile tip approaches a soil element and decrease to a residual value afterwards ('friction fatigue'). The peak value of soil stresses increases with soil density. The residual value was found to be close to the earth pressure at rest. In case of vibratory pile installation, soil stress developments range from 'very similar to impact pile driving' to 'no effect', depending on vibratory driving parameters. High soil stress changes due to vibro-driving correlate with high permanent displacements per vibration cycle. Both peak and residual radial soil stresses need to be considered for pile driving simulations, as they are the basis for the pile shaft friction. A novel formulation for the 'friction fatigue' phenomenon during impact pile driving is presented. In contrast to current practice, the authors suggest using different approaches to calculate the peak skin friction for impact and vibratory driven piles. The soil stress at the end of driving is a key driver for the pile's load bearing behaviour. As increased soil stresses may remain after pile installation, especially near the pile tip, different soil stress developments have implications for the axial or lateral pile design.

An assessment of pile driveability analyses for monopile foundations. Presented by : Y. Kourelis

ABSTRACT

Several methodologies to predict the static soil resistance to driving (SRD) available in the literature have found wide use in the offshore industry over the last decades. These range from simple methods that require few soil strength parameters to more advanced semi-empirical methods that correlate the driving resistance to cone penetration test measurements. These methods were primarily developed based on driving records for piles less than 2.5m in diameter i.e. much smaller than the monopiles currently used in the offshore wind industry today. The aim of this study is to evaluate the accuracy of some of the most widely used SRD prediction methods when employed for driveability analysis of large diameter monopile foundations, by comparing the predicted SRD profiles with the driving records of 6.5m diameter monopiles installed in the Danish region of the North Sea.

Drivability aspects of tubular piles in chalk. Presented by : R. Brouwer

ABSTRACT

The Colne Valley Viaduct is a planned bridge, part of the High Speed line HS2 phase 1, designed to be 3.4 km long. VolkerStevin Ltd. has been commissioned by Align to install approximately 394 no. tubular piles over four different jetties (Jetty A to D) required for the construction of the HS2 Colne Valley Viaduct. Geobest B.V., as subcontractor to Volker Stevin, performed several driveability studies for this project. All steel tubular piles, of different dimensions and penetration lengths, will be installed in hard chalk layers. The main challenge has been to predict the expected pile resistance (SRD), as pile driving in chalk is subject to significant uncertainty. Literature also provides little and also varying guidance on how to estimate soil resistance to driving in chalk. In this document, the process leading to the prediction of the expected pile resistance is discussed. Driving records are then used to verify the performed prognosis and to back calculate the driving resistance in the chalk layers. In conclusion, insights are given on how to approach future chalk projects.

Vibro driving testing in confined space for offshore wind farm application. Presented by : A. Ta

ABSTRACT
An onshore vibro driving testing of large-scale piles (2.5 m diameter) was carried out in order to validate an innovative foundation design that is needed to overcome challenging soil conditions encountered at an offshore wind farm in France. The foundation concept named DSD (drill-sand-drive) is to replace the hard soils using drilling by engineered granulars that are then compacted to design density though which monopiles are vibrodriven. Three tests were conducted covering different levels of soil compaction from low to very high and that was closely controlled using CPT. The pile driving monitoring comprised PDA sensors, vibro hammer parameters, crane hook load as well as water pressure along the external pile shaft to evaluate the liquefaction extent. The tests ultimately produced the confinement configuration induced by the drilled hole and the surrounding stiff soils and provide evidence of its impact on noticeable amplification of vibro compaction and vibro driving.

Finite element simulation of high-strain dynamic testing of open-toe, steel pipe piles for estimation of geotechnical axial resistance. Presented by : Carvajal/Tara

ABSTRACT
High-strain dynamic and static loading tests were performed on three open-toe, steel pipe piles driven in a fluvial deposit comprised mainly of compact sand. The pile diameter varied from 0.762 m to 1.524 m and the embedment from 36.5 m to 40 m. Axisymmetric finite element analyses (FEA) were performed with PLAXIS2D to determine the soil properties that control the shaft and the toe resistance of the piles using both dynamic and static load testing data. The geotechnical resistance of the piles obtained with FEA were generally 40% to 70% higher than that obtained with 1D WEA and CAPWAP. The FEA showed that the underestimation of the ultimate pile resistance is at least partially due to the inability to mobilize the toe resistance because of the small peak displacements induced at the pile toe with conventional high-strain dynamic testing (5 mm to 10 mm) in comparison to the large displacements required to mobilize the toe resistance in a static test (65 mm to 140 mm). A procedure is developed to improve the estimation of the ultimate pile resistance for design using FEA and high-strain dynamic load test data.

Modelling and simulation of vibratory driven sheet piles – development of a stop criterion. Presented by : Andersson

ABSTRACT
During excavations, steel sheet piles are often installed through vibratory driving. This is especially effective in soft soils. However, when installing sheet piles in other soils such as glacial till, there is a risk of impact with boulders that may damage the sheet pile toe. This may result in unnecessary time- and cost intensive measures to ensure stable and watertight excavation. Hence, there is a need for a criterion to stop the driving before the sheet pile is severely damaged. The purpose of this paper is to investigate how numerical models may be used to simulate a sheet pile encountering a boulder during vibratory driving, and to investigate the possibility of developing a stop criterion based on the outcome of the models. Two numerical models were created to simulate the vibratory driving: a uniaxial multi degree of freedom model and a finite element (FE) model, by using the numeric platform MATLAB and the FE software ABAQUS respectively. The simulations were carried out through explicit time integration in both models. The external actions on the sheet pile, i.e., the vibratory driving force, soil resistance and obstacle resistance were estimated with methods found in literature. The models were then calibrated against a field study by using its results as input to the models. The encounter with a boulder, was simulated in different ways. In the uniaxial model, the contact was modeled by an elastoplastic contact force and in the FE model a solid body with high stiffness was introduced. The results of the numerical models show promising resemblance with the results of the field study. Both the global driving speeds and the accelerations of the sheet pile corresponds well with the field study for both models. The simulations indicate that boulder impacts may be detected by monitoring changes in acceleration amplitude traveling along the sheet pile. This suggest that a stop criterion for vibratory driving could be based on abrupt changes in acceleration amplitude. By creating a device with accelerometers detecting a significant increase in acceleration amplitude, damage to the sheet pile could be prevented. Although it should be mentioned that at weak impact points of the sheet pile cross section only small changes in the accelerations were seen in the simulations.

Offshore Installation of Piles in Egypt. Presented by : A. El-kadi

ABSTRACT
The paper contains the case history of the installation and testing of offshore foundation piles in the Gulf of Suez in Egypt. For the installation of two offshore jackets for the oil and gas industry piles of over 100 m length had to be driven. Because of this length the piles were driven in sections, with pile driving monitoring throughout the entire installation. The soil investigation at the project site indicated the potential for voids at several depth as the cone resistance became as low as close to zero in a silt layer from 73,5 till 100 m below seabed. The papers show the results of the pile driving monitoring. At final penetration depth restrikes were performed to determine the pile capacity of the pile through a Dynamic Load Test (or High Strain Dynamic Test). The process of modelling the soil strata, the adjustments to that soil model as part of the signal matching process as well as a discussion of the generated test results are also presented in the paper.