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PHD OPPORTUNITY – RESEARCH IN OFFSHORE RENEWABLES OCTOBER 2024 (3 YEARS, FULLY FUNDED)

HELICAL PILE: PHYSICAL AND NUMERICAL MODELING FOR MARINE GEOTECHNICAL APPLICATIONS

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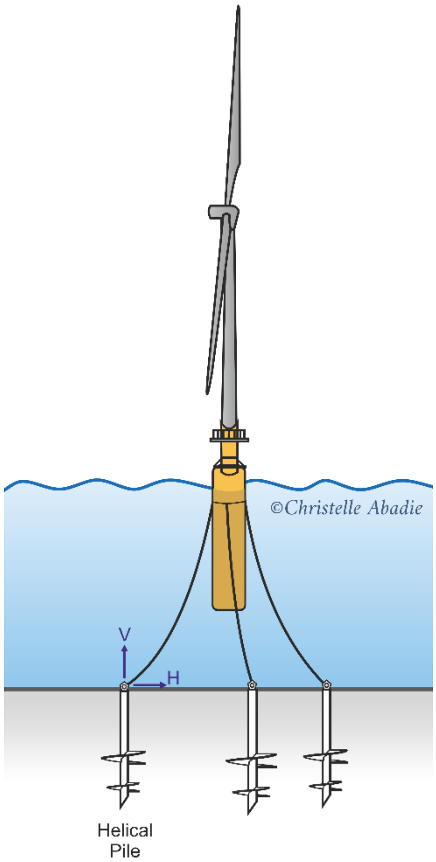
PhD specialty: Geotechnical Engineering, Offshore Geotechnics

1 | Project description



With the development of renewable energies and the need to shift construction methods towards low environmental impact solutions (reduced carbon footprint and reuse/dismantling), there is now a booming market for a new type of foundation, e.g. for light structures (solar panel supports), individual houses or developments in protected or tourist/recreation areas (pontoons/bridges/barges) or for temporary structures. There are also other applications that are currently being explored, concerning anchors (operating in traction) in aquatic or marine environments e.g. floating wind turbines or solar panels on barges, or wave energy converters.

In the field of marine geotechnical engineering, the helical pile (HP) consists of a metal shaft on which one or more helices are welded. Because they are easy to install and decommission, most often, these helical piles are of small dimensions (length of a few meters, diameter of the helix of about 30 cm). They are also silent to install, which is an important requirement for installation offshore and onshore. Despite their clear advantages, the design of HP is neither covered by the current Eurocodes nor by the specifications and standards. In addition, the cyclic loads that the HP experiences are likely to cause a "fatigue" issue at the shaft-ground interface and in the vicinity of the helix, which can lead to long-term degradation and performance issues. Therefore, research and development work on the long-term cyclic behaviour of HP is required to provide a thorough understanding of the performance degradation risk and implement design practices for the industry.

Keywords: offshore wind, helical pile, cyclic loading, model implementation, centrifuge modelling

2 | Project Objectives

The research project will tackle the following 6 objectives:

- elucidate the most appropriate methods of geotechnical investigation to build semi-empirical design guidelines (we will focus initially on the case of cohesionless soils and then move to the case of cohesive soils),
- understand the possible methods of installation for the HP, and how to characterize the HP response to torque phases of the installation and axial push phases of the
- highlight the consequences of an "imperfect" installation (different from a one-step drive-by-turn) on its subsequent behaviour,
- establish a simple model to predict the bearing capacity of these piles: we will distinguish the function in "anchorage" (traction), from the function in compression, but also the effect of cyclic loading,
- understand the influence of the geometrical configuration (one/two helices, for example) on the bearing capacity,
- devise an experimental test campaign to validate/control the long lift/behaviour (short term/long term)?

The Ph.D. student will work towards these objectives, to propose design guides that are adapted to the field of use of these piles and their associated stresses.

3 | PhD learning outcome

The Ph.D. student will first develop skills and knowledge in the field of physical modelling and experimental testing on the geotechnical centrifuge. The candidate will also explore scaling laws to appropriately design the tests and analyze the data of the HP pile tests.

In parallel, the Ph.D. student will develop skills in numerical modelling of geotechnical problems, in particular considering the challenging case of cyclic loading of geotechnical foundations.

Finally, the Ph.D. student will study the installation phase of these piles (experimental and numerical approaches with the consideration of large soil deformation) and attempt to correlate the measured parameters (force, torque, driving speed etc.) with the bearing capacity of the pile.

4 | PhD project timeline

Technical approach

The work will be based on existing analytical and numerical developments as well as on experiments on centrifugal scale models:

Literature Review: a review of the scientific and technical literature, will permit to evidence the recent advances in the design of helical anchors, in compression, in tension under axial and non-axial loading, as well as under transverse loading, both under static and cyclic loads. The methodology developed during the SOLCYP project and the results of the WEAMEC REDENV-EOL project will be used. A study and summary of the numerical techniques for large deformation simulations and the impact of advanced constitutive models on numerical simulations will also be proposed.

Comprehensive analysis of the installation phase: measure the torque, as well as the vertical force required for driving HPs which is similar to the installation in situ; HPs of different geometries will be studied, with either an enlarged barrel at the top or multiple helices of the same or increasing diameter (for lower depths). Correlations with in situ tests will be established, in particular, in the cases of over-rotation or under-rotation (when the installation advancement is different from one-step drive-by-turn).

Study of the loading (vertical and inclined) directions: For one or two helical pile geometries the effect of monotonic loading inclination from horizontal to vertical (e.g. 0°, 30°, 45°, 60°) will be investigated. These tests will be performed in a centrifuge on loose and dense sand. Correlations with the soil investigation tests will be made to guide the design of HPs. This PhD relies on a multi-approach (Physical and numerical modelling) to study the behaviour of HP to establish dimensioning rules that are adapted to future practical applications, for example floating wind turbine anchors, etc.

Experimental work

Conducting on-site foundation testing in offshore environments proves cost-prohibitive. Therefore, within offshore geotechnics, the industry relies on reduced-scale experiments performed in the geotechnical centrifuge. Placing a reduced-scale model within a macro-gravity field aims to replicate the same stress state on the model as experienced by the full-scale prototype. Consequently, a 1/100th scale model, subjected to a 100×g macro-gravity field (equivalent to 100 times Earth's gravity), mimics the behaviour of the full-scale system.

The University of Gustave Eiffel, located on the Nantes campus, boasts the exclusive geotechnical centrifuge in France and ranks among the top five biggest centrifuges in Europe. During this PhD, an experimental campaign involving reduced-scale models will be performed in the centrifuge, enabling tests on anchor subjected to multidirectional, and cyclic tension loading. Performing centrifuge tests permits to control of environmental and boundary conditions, enabling a systematic and rigorous analysis of the anchoring system.

The PhD will therefore involve conducting tests in the geotechnical centrifuge on selected geometries of helical piles. To find the stability domains, for certain inclinations, configurations and cyclic loadings with different amplitudes will be tested. A loading test procedure adapted to this type of foundation will be proposed. In addition, multidirectional loading will also be performed.

Geometry of the helical pile: In the case of multiple-helixes piles, the strategy of dimensioning the helixes will be studied, so that each helix brings a contribution to resistance, considering the redesign during installation.

Numerical simulation

The first task will be to establish a framework for the simulation of large deformations. At this stage a simple behavior law can be used. This will permit to learn 3D FE modelling in a simple yet efficient way prior to modifying the constitutive model of the soil from a simple behavior law to an advanced constitutive model adapted for cyclic loads. Calibration of a series of model parameters will be achieved and validation of the numerical model against the experimental data will provide confidence in the final model. The validated numerical model will finally be used for parametric analysis and simulation of other cases, and the validated numerical model will be extended to the simulation of real situations..

5 | Collaboration

A short stay (4 weeks) in Brazil is also planned for the Ph.D. candidate within the framework of this program, according to the work progress and experimental plans in connection with the University of Sao Paulo.

6 | Candidate’s profile

We are seeking dynamic candidates who possess a robust foundation in geotechnical engineering. Undergraduate/Master students in general engineering / civil engineering / geotechnical engineering / offshore geotechnical engineering are particularly welcome. Experience in programming, numerical modelling (e.g. Finite Element Analysis) and foundation design is beneficial, but not obligatory for this position. Proficiency in the English language is essential for the role.

7 | Location and Funding

Location

The PhD will take place in the Geotechnical Centrifuges Laboratory on the Nantes campus of Gustave Eiffel University. A brief visit of a few weeks to the laboratories of the University of Sao Paulo in Brasil may be considered as part of this project.

Funding

The Ph.D. contract granted by IFSTTAR is for the time being 1858€ gross per month during the first two years, and 2125€ gross per month during the third year. Teaching vacations or industrial missions can complement these PhD contracts.

8 | How to apply

To apply, please email:

- A CV
- A cover letter detailing your suitability and motivation for this position
- A copy of your transcript

Email to zheng.li@univ-eiffel.fr and luc.thorel@univ-eiffel.fr . Please, do not hesitate to get in touch for further information.

Further information:

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