Université Gustave Eiffel
Campus de Nantes
Allée des Ponts et Chaussées
44340 Bouguenais

PHD OPPORTUNITY – RESEARCH IN OFFSHORE RENEWABLES (3 YEARS, STARTING IN OCTOBER 2026)

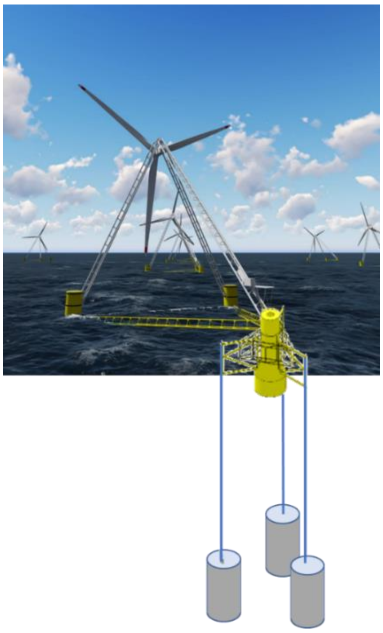
Macroelement Modeling of Rate-dependent Behavior of Suction Anchor in Clay under Monotonic and Cyclic Loading

Supervisors: Dr. Matthieu Blanc and Dr. Zheng Li

Université Gustave Eiffel, Nantes, France

PhD specialty: Geotechnical Engineering, Offshore Geotechnics

1 | Context



Climate change caused by greenhouse gases is having an increasingly severe impact on human society. The urgency of identifying sustainable energy alternatives, such as solar, wind, and hydropower, has never been greater. Among these, wind energy stands out as a highly cost-effective, clean, and sustainable source of energy for societies worldwide. Approximately 70% of the Earth's surface is covered by oceans, representing an area of 140 million square miles with enormous potential for floating wind turbine applications. According to the International Energy Agency (IEA) [1], the global technical potential of offshore wind energy is estimated at 120,000 gigawatts (GW), enough to meet 11 times the projected global electricity demand in 2040.

In Europe and particularly in France, floating offshore wind turbines are approaching technological maturity and are progressively transitioning from pilot projects to large-scale commercial wind farms. As floating wind farms expand into deep-water regions, robust and reliable anchoring systems become essential to ensure structural integrity under severe environmental loads. Among the available foundation solutions, suction anchors are widely adopted in clay seabeds, particularly for tension-leg platforms (TLPs) and floating offshore wind turbine mooring systems [2]. Their installation efficiency, high tensile capacity, and adaptability to deep-water environments make them highly attractive.

Although suction anchors in clay have been extensively studied under monotonic loading conditions, their rate-dependent behavior remains insufficiently understood [3]. Therefore, improved modeling strategies are needed to accurately capture the influence of loading rate on both short-term extreme resistance and long-term cyclic performance in floating offshore wind systems.

Keywords: suction anchor in soft clay, rate-dependent behavior, numerical simulation, macroelement modeling

2 | Problem Statement

Three main challenges arise:

•Coupled Hydro-Mechanical Rate Effects: The uplift response of suction anchors in clay depends on the interaction between loading rate, soil consolidation, and pore pressure dissipation. Current design approaches typically consider only fully drained or undrained conditions, neglecting the continuous transition between these states. Capturing this rate-dependent hydro-mechanical coupling in a simplified yet physically consistent framework remains a key challenge.

•Cyclic Loading and Accumulation Effects: Under cyclic loading from wind and waves, suction anchors may experience pore pressure buildup, stiffness degradation, and progressive displacement accumulation. While monotonic behavior is relatively well understood, a unified description of rate-dependent cyclic response is still lacking, particularly for long-term performance assessment.

•Fast and efficient numerical tool for the analysis: currently, the response of suction anchors is predominantly investigated using coupled finite element simulations. While these approaches can accurately reproduce hydro-mechanical behavior, they are not suitable for rapid design assessments or large-scale dynamic analyses of floating wind systems. A fast and efficient modeling framework for predicting monotonic and cyclic pullout behavior is therefore needed.

3 | Technical approach

This study relies on a combined strategy of coupled finite element (FE) modeling and structural-level macroelement modeling[4-5]:

First, a robust FE model capable of reproducing coupled hydro-mechanical rate effects will be developed to simulate the short-term monotonic pullout and long-term behavior of the suction anchor under cyclic loading. The model will explicitly capture rate/time dependency through the evolution and dissipation of pore pressure and rate-dependent resistance mobilization. The FE model will be extensively calibrated and validated against a large set of geotechnical centrifuge test data. The validated FE model will serve as a strong complement to centrifuge testing by providing additional information, which is essential for macroelement development.

Second, based on the validated FE model and centrifuge evidence, a rate-dependent elasto-viscoplastic macroelement will be established at the structural level in terms of generalized displacement and force. The nonlinearity and the rate-dependency of the macroelement will be established under the framework of elasto-visoplasticity. The proposed macroelement will be validated against both centrifuge results and FE simulations, enabling a fast and accurate evaluation of the rate-dependent performance of the suction anchor in the structural level.

4 | Novelty

The core innovation of this research lies in establishing a cross-scale modeling framework that bridges high-fidelity finite element simulations and structural-level macroelement modeling. The novelty of the project lies not only in advancing the fundamental understanding of rate-dependent anchor behavior, but also in transforming complex multiphysical simulations into an efficient and robust engineering numerical tool for decision-making in offshore design practice.

5 | Expected Outcomes

• Systematic calibration and validation of FEM numerical model against centrifuge test data;

• A robust, rate-dependent elasto-viscoplastic macroelement will be established, capable of reproducing the rate-dependent behavior of suction anchor response under monotonic and cyclic loading.

• Recommendations for short- and long-term performance optimization.

6 | Supervision

PhD director – Dr. Matthieu Blanc (HDR) has over 15 years of experience in centrifuge physical modeling applied to offshore geotechnics. In 2021, he was appointed as the director of the Geotechnical Centrifuges (CG) laboratory within the GERS department. Matthieu Blanc's current research explores topics related to physical modeling in geotechnics, particularly with the geotechnical centrifuge. He mainly works on soil-structure interactions under complex loading, such as soil reinforcement, and deep and shallow foundations. Recent applications are oriented towards foundations and anchoring systems for marine renewable energies. The ongoing challenge for each of these topics is to observe and understand the phenomena, and also to obtain appropriate experimental data to compare with numerical or theoretical models. Dr. Matthieu Blanc received in 2018 the Jean Kérisel Prize rewarding the young engineer/researcher in geotechnics served by the French Society of Soil Mechanics.

PhD supervisor – Dr Zheng Li. Zheng Li joined the GERS-CG laboratory at Université Gustave Eiffel in 2019. Zheng LI is carrying out his studies in the field of physical centrifuge modeling and numerical modeling. His research specializes in constitutive modeling, soil-structure interaction, and large deformation analysis, particularly in macroelement modeling of deep pile foundations and offshore structures such as soil-caisson interaction in sand and soil-pipeline interaction in clay.

7 | Collaboration

This Ph.D research is closely connected to PAREF project which is crucial to creating competitive and sustainable solutions for floating offshore wind turbines, adapted to deep waters (https://www.ten.com/en/media/press-releases/technip-energies-universite-gustave-eiffel-valeco-and-open-c-foundation). The experimental data of this Ph.D study will be supported by the PAREF project

8 | Candidate's profile

We are seeking motivated candidates who possess a solid foundation in geotechnical engineering. Undergraduate/Master students in general engineering/civil engineering/geotechnical engineering/offshore geotechnical engineering are particularly welcome. The passion in constitutive modeling is highly appreciated and the experience of FEM modeling using Abaqus is preferred. Proficiency in the English language is essential for the role.

9 | Location and Funding

Location

The PhD will take place in the Geotechnical Centrifuges Laboratory on the Nantes campus of Gustave Eiffel University. Please visit the website of the lab for more information: https://cg.univ-gustave-eiffel.fr/en/

Funding

The research funding for this project requires joint efforts from the Ph.D. candidate and the supervisors, with the application process in two stages:

Stage 1: The supervisor conducts interviews to identify and select an outstanding Ph.D. candidate (March to April).

Stage 2: The supervisor and the selected candidate will collaboratively develop and present a research plan to the academic committee to evaluate the novelty of the project as well as the academic excellence of the Ph.D. candidate and to validate the application for funding (around May).

10 | 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 Dr. Zheng LI: zheng.li@univ-eiffel.fr; Dr. Matthieu Blanc: matthieu.blanc@univ-eiffel.fr;

The online application is open, please find the application access:

https://amethis.doctorat.org/amethis-client/prd/consulter/offre/2929

Please, do not hesitate to get in touch for further information.

References

[1]. IEA, Offshore Wind Outlook 2019, 2019.

[2]. K. H. Andersen et al., “Suction anchors for deepwater applications,” Frontiers in Offshore Geotechnics ISFOG 2005 - Proceedings of the 1st International Symposium on Frontiers in Offshore Geotechnics, pp. 3–30, 2005.

[3]. Iskander, M., El-Gharbawy, S., & Olson, R. (2002). Performance of suction caissons in sand and clay. Canadian Geotechnical Journal, 39(3), 576-584..

[4]. Li, Z., Kotronis, P., Escoffier, S., & Tamagnini, C. (2016). A hypoplastic macroelement for single vertical piles in sand subject to three-dimensional loading conditions. Acta Geotechnica, 11(2), 373-390.

[5]. Jin, Z., Yin, Z. Y., Kotronis, P., Li, Z., & Tamagnini, C. (2019). A hypoplastic macroelement model for a caisson foundation in sand under monotonic and cyclic loadings. Marine Structures, 66, 16-26.