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

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

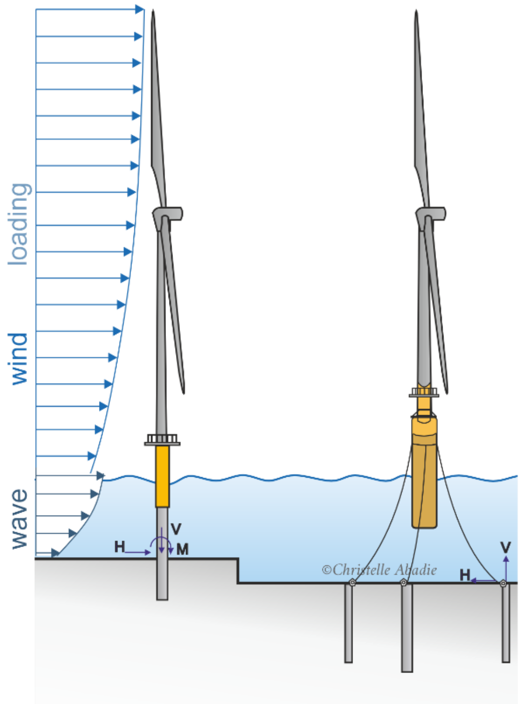
PHYSICAL AND NUMERICAL MODELLING OF SHARED ANCHORS FOR FLOATING OFFSHORE WIND TURBINES

Supervisors: Dr Christelle Abadie[1], Dr Matthieu Blanc[1]
Potential Collaborators: Dr Ana Page[2] and Dr Sunniva Indrehus[2]

[1] Université Gustave Eiffel, Nantes, France
[2] NGI, Oslo, Norway

PhD specialty: Geotechnical Engineering, Offshore Geotechnics

1 | Project description



Offshore wind plays a pivotal role in the transition to renewable energy; however, the substantial construction costs associated with anchoring systems for deep-sea wind turbines present a significant challenge. The optimization of foundation geometry, ensuring resilience throughout the wind turbine's lifespan against substantial cyclic loads from diverse directions—such as wind, currents, and waves—remains a key technological barrier.

Concurrently, the advancement of "floating" offshore wind turbines is underway in France, Europe, and globally. These floating turbines are nearing technological maturity, and are almost ready to be integrated into wind farms comprising several dozen units and plugged into the energy grid. To mitigate installation costs, streamline geotechnical investigations, and optimize anchorage maintenance, anchor sharing emerges as a promising solution. Each turbine is tethered to the seabed by three anchor lines, and each anchor has the capacity to secure lines for three distinct turbines, spaced 120° apart. Consequently, the number of anchors required for a wind farm could be reduced by more than half.

However, anchor sharing introduces a complex loading pattern characterized by significant multi-directionality, an aspect insufficiently explored in offshore geotechnics. Published studies predominantly draw from the oil industry, which did not entail the deployment of shared anchors. Additionally, for safety considerations, anchor lines on oil platforms are frequently tripled or quadrupled to address the risk of potential line failures. Implementing such measures in offshore wind would result in prohibitive costs, rendering this solution impractical. Consequently, a comprehensive understanding of the impact of these cyclic multidirectional loads on anchoring systems is imperative, with rigorous modelling for design practice.

Keywords: offshore wind, cyclic loading, plasticity theory, model implementation, centrifuge testing

2 | Project Objectives

This PhD will focus on soil-anchor interaction behaviour subjected to multidirectional and cyclic tension loadings.

Research Axis 1: Experimental Centrifuge Modelling

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 environmental and boundaries conditions, enabling a systematic and rigorous analysis of the anchoring system. The tests campaign's objectives are twofold: i) understand the key mechanisms driving long-term behaviour of anchor sharing and ii) provide precise and reliable data for calibrating a numerical model. These centrifuge tests are poised to establish one of the pioneering databases on anchor behaviour under cyclic multidirectional loading.

Research Axis 2: Numerical 3D Finite Element Modelling

The second research axis aims to develop a numerical model to analyse the behaviour of a shared anchor using 3D finite element method. The critical aspect of this stage lies in selecting the constitutive model for the soil and the soil/anchor interface, taking into account the influence of load cycles. This numerical model will undergo calibration based on impetus data from the centrifuge tests.

The calibrated model will serve two primary purposes: i) conduct a comprehensive parametric study on various key elements of shared anchor design, thereby minimizing the number of required centrifuge tests, and ii) obtain data that are not easily accessible through experimentation (such as stress state in the soil, local pressure on the anchor, soil failure mechanisms, etc.).

Research Axis 3: Development of a Simplified Design Tool for Engineering Practice

After an in-depth examination of the anchor's behaviour through experimental centrifuge testing and 3D numerical modelling, the next step involves simplifying the problem to create an engineering tool for the design of shared anchors for floating wind turbines. To achieve this, the anchor will be represented by a 1D finite element (a beam) or a macro-element tailored for industrial practice.

Modelling the foundation response to cyclic multidirectional loading necessitates the consideration of adverse effects stemming from repeated cyclic loading, such as accumulated deformation and change in stiffness, while also addressing coupling effects between diverse loading directions. As of now, there lacks a straightforward numerical model that comprehensively addresses these intricacies.

However, there are specialized models, rooted in the principles of kinematic hardening plasticity. First, the HARM model, created in 2017, permits to capture the effects of repeated cyclic loads over very many cycles. Second, the REDWIN model has been recently developed to address the coupling effects between different loading directions. The objective is to numerically and mathematically integrate these two models, enabling a thorough representation of foundation responses. The final model will be released as open source on a downloadable platform, potentially revolutionizing the design and durability of offshore wind turbine foundations.

3 | PhD project timeline

The Ph.D. program will dedicate the initial two years to executing the experimental campaign (axis 1) and developing the advanced numerical model (axis 2). In the concluding year of the PhD, the emphasis will shift towards applying the acquired knowledge to the development of an engineering tool for design (axis 3) and disseminating the thesis work through an Open Source platform and paper publications.

4 | Supervision

PhD director - Supervision Rate: 51%. Matthieu Blanc (HDR) has over 13 years of experience in centrifuge physical modelling applied to offshore geotechnics.

PhD supervisor - Supervision Rate: 49%. After completing her PhD in 2015 at the University of Oxford on the cyclic behaviour of monopiles and the development of the HARM model, Christelle Abadie continued her research at the University of Cambridge as an assistant professor, focusing on geotechnics for sustainable infrastructure development in the context of climate change. Recruited at Gustave Eiffel University at the end of 2023, she continues to explore topics related to the emergence of new foundations for Marine Renewable Energies.

5 | Collaboration

As the REDWIN model was developed by a researcher from the Norwegian Geotechnical Institute (NGI), this project will involve collaboration with the NGI research laboratory. During this collaboration, expert guidance on the development of constitutive models will be provided to the supervisory team and the selected Ph.D. candidate to advance the numerical model. A brief visit to Norway for a few weeks may be considered as part of the PhD to facilitate this collaboration.

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 Norwegian Geotechnical Institute in Oslo, Norway, 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 Christelle.abadie@univ-eiffel.fr . Please, do not hesitate to get in touch for further information.

Further information: https://www.ifsttar.fr/offres-theses/sujet.php?num=3886&num_session=1&ver=fr