PhD position at Université Gustave Eiffel, Nantes Campus, France
(2022-2025, start date 1st October 2022)

Subject:	**Soil improvement by rigid inclusions: application to wind turbine foundations under seismic loading**
University:	**Université Gustave Eiffel**
	Since January 1, 2020, Ifsttar has become Gustave Eiffel University! Website of Université Gustave-Eiffel (Click for more information)
Department:	**Department of Geotechnical engineering, Environment, Natural hazards and Earth sciences (GERS)**
Laboratory:	**Centrifuges for Geotechnics (CG) at Nantes**
Contact:	**Sandra ESCOFFIER**: sandra.escoffier@univ-eiffel.fr;
	Zheng LI : zheng.li@univ-eiffel.fr
	Luc THOREL: luc.thorel@univ-eiffel.fr

1 Background

Today with the specter of global warming and climate change looming over us, there is a need for the industry to find energy sources free of CO2. Under this motivation, more attention has been paid for renewable energy. Over the past 11 years, among all the renewable forms of energy (wind, solar, geothermal, and hydroelectric) wind energy capacity has increased significantly (Letcher, 2017). The onshore wind turbine was also greatly developed. For the construction of wind turbine on regions with weak soils, the installation of a spread foundation directly over an improved soil by Rigid Inclusions (RI) becomes a more and more popular solution (Mohamed, 2016; Pham et al., 2018).

Usually, RIs are designed to take up directly vertical stresses and therefore previous research has mainly focused on the behavior of RI-reinforced compressible soils subjected to uniform vertical static loads. Less attention has been paid to the study of the response of RI reinforced soils under horizontal seismic loading and the associated soil-structure interaction. However, the foundation system consists of rigid inclusions (RI) combined with a granular mattress load transfer platform (LTP) (also known as unconnected or disconnected foundation) can change the response of the soil and superstructure when subjected to complex loads such as seismic loads. It is also advisable to verify how compatible the stresses caused by seismic loading are with the strength requirements for rigid inclusions. Moreover, recently, the seismic hazard of France was recently re-evaluated and new seismic maps were developed (Douglas et al., 2013). It is required that French infrastructures to be implemented with complementary safety standards and new seismic safety margins for foundations resting on soil reinforced by RI.

This Ph.D project is quite innovative since there is a lack of experimental researches on the performance of the soft soil reinforced by RI and on the seismic behavior of the superstructures built on it. Although there are some literature available for example the centrifuge work of Allmond and Kutter (2014), Loli et al. (2015) and Ha et al. (2019). However, none of these test campaigns involve clay masses and the majority of the tests were performed in the absence of a load transfer platform.

Meanwhile, this Ph.D study will have the chance to be the continuity of the ANR ASIRIplus_SDS project[1] in which a series of preliminary and exploratory tests are currently conducted. The continuous efforts in this field will allow the capitalization and the profit of the knowledge acquired during this exploratory phase. In parallel with numerical modeling, this Ph.D work could lead to technical recommendations within the framework of the construction of on-shore wind turbines on weak soils.

[1] ASIRIplus_SDS in French and ASIRIplus_SDS in English (Click for more information)

2 Objective

The objective of this study is to provide knowledge on the performance of IR under seismic loading using physical modeling in a centrifuge and numerical modeling. Within this framework, based on exploratory tests that are being carried out within the framework of the ANR ASIRI+ SDS project, the influence of several parameters on the behavior of a slender structure based on an IR-reinforced soil will be studied through different test configurations:

- Study of the kinematic interaction induced by the presence of IR (test configuration without superstructure).
- Study of the influence of the presence of IR on the rotational behavior of a superficially founded superstructure (case of a high center of gravity)
- Effect of the load transfer mattress on the seismic behavior
- Effect of the mechanical characteristics of the soil on the performance of IR.

3 Technical approach

The technical strategy of this study will be a combined approach of experimental (70%) and numerical technique (30%). The experimental study will provide important proof on the physical phenomena and essential data for numerical modeling; As an effective complement to the experimental work, the calibrated numerical model is more flexible for providing information and parametric studies. The planned steps are the following:

- In the first phase, based on the results of exploratory tests conducted under the project ANR ASIRIplus_SDS, the doctoral student will conduct a series of tests on the kinematic interaction induced by the presence of IR based on two different configurations. This work will provide information on the influence of the configuration of the RI configurations. This point will be extended by numerical parametric studies once the numerical model is calibrated and validated.
- In the second phase, after the selection of an IR configuration, based on the results of the first phase, a series of tests aiming at highlighting the performance of IR reinforced soft clayey soil on which slender structures are built will be carried out. In this phase, based on the preliminary results obtained within the framework of the ANR ASIRIplus_SDS project, 2 superstructures (with single degree-of-freedom) which have same fundamental frequency but different height of center of gravity will be tested.
- In the third phase, the study will be further extended to the study of the influence of load transfer platform (which is a current question in practice) and the mechanical characteristics of the compressible layer on the seismic performance of the IR
- In parallel, the calibration and validation of the numerical model will be carried out on the basis of the modeling of a centrifuge test and will be performed on the Abaqus FEM platform. The numerical model will provide information that is difficult to measure in physical models and will highlight the IR-soil-foundation-structure interaction mechanisms under seismic action. The validation of the numerical model with experimental data is a key step. Once validated, the numerical model will allow parametric studies on the behavior of IRs.

4 Working conditions

In this project, the experimental program will be carried out at Université Gustave Eiffel - Campus de Nantes (ex IFSTTAR) within the centrifuge team – (GERS-CG)[2]. This centrifuge is the only one equipment for geotechnical applications in France, and one of the largest centrifuges in the world (radius of 5.5m, 2 tons on board, maximum acceleration of 100×g). The geotechnical centrifuge is equipped with an embedded earthquake simulator which allows the application of mono (sine) or multi-frequency solicitation according to 1 direction with a prototype maximum acceleration of 0.5g.

5 Candidate profile

The candidate must hold a master's degree with a background in geotechnics, geomechanics or seismic geotechnics. Knowledge in experimental and finite element modeling is highly appreciated. Ideally, the candidate should also have knowledge of Matlab/Python and data processing. As the experimental work is carried out within an experienced technical team, the candidate must have a team spirit in order to carry out the experimental campaign.

6 Salary

The PhD contract granted by Université Gustave-Eiffel 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.

7 Application procedure and important date

It is **strongly recommended** to contact the laboratory (PhD supervisor or head of the laboratory) in charge, to finalise with them the scientific contents of the topic, provided of course that the laboratory is interested by your application.

- The candidates contact the PhD supervisor and agree with him/her of the opportunity of an application.
- The candidates apply on the web page describing the chosen topic. Registration to get a password **starts on Tuesday 1st February, 2022 08:00 AM**
- Then, the candidate receives an email containing the link to create his own password.
- They fill the form and submit the requested annex documents, with the help of the supervisor.
- The candidates can modify or complete their online dossier **until Friday 22nd April, 2022 23:59 PM**
- The head of the laboratory completes your dossier with his/her opinion via an online form Wednesday **before Thursday 28th April, 2022 23:59 PM**

[2] Website of laboratory of Geotechnical centrifuge modeling (Click for more information)

- A first selection of the dossiers will be made by Ifsttar Scientific Directorate in the following week The pre-selected candidates will receive a convocation for an audition which will take place **Thursday 19th May, 2022 08:00 AM**

For the application access, please refer to the following links:

- French version (cliquez sur le bouton: Je candidate sur cette thèse): https://www.ifsttar.fr/offres-theses/sujet.php?num=3136&num_session=1&ver=fr
- English version (click the button: I apply for this PhD): https://www.ifsttar.fr/offres-theses/sujet.php?num=3136&num_session=1&ver=an

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