PhD OPPORTUNITY – RESEARCH IN GEOTECHNICAL EARTHQUAKE ENGINEERING

COMPARISON OF THE SEISMIC PERFORMANCES OF RIGID INCLUSIONS UNCONNECTED PILES AND PILE RAFT FOUNDATIONS

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PhD specialty: Geotechnical Earthquake Engineering

1 | Context

Rigid inclusions (RI's) are long vertical slender elements used to transfer loads of the overlying superstructure, or embankment, throughout compressible soils to, in most of the configurations, underlying competent layers. When used as a part of a foundation system of a superstructure they differ from piled raft foundation and unconnected piles by the presence of a Load Transfer Platform (LTP) between the rigid inclusion heads and the superstructure. In addition, in common design, rigid inclusions differ from the piles by their bending and axial stiffness that are lower; exceptions can be encountered, for instance, in the case of foundation system for bridge pier. Rigid inclusions are installed as a grid pattern into the weak soil and are used to increase the bearing capacity and reduce foundation vertical settlement. They are used typically as an economic substitute for piles either in the case of thick soft layers making the use of piles unsuitable, or in cases where the execution of the rigid connection between the head of the piles and the shallow foundation is difficult.

In recent decade, based on researches on the performances of RI's and the effect of the LTP under static monotonic loads, a set of recommendations for the conception and design of a RI's reinforcement system under static load was proposed (ASIRI National Project, 2012). In seismic region RI's were firstly applied in the Rion-Antirion bridge (Pecker, 2006) and progressively become popular. Several researches have highlighted that the LTP can be regarded as a GSI system (Geotechnical Seismic Isolation) as it can reduce the transition of energy between the soil and the footing by allowing a certain amount of sliding between the footing and the RI's head. In the last decade, some studies on RI's foundation system, under dynamic loads were published (Ha et al., 2019, Liang et al., 2021, Baziar et al., 2018, Shen et al., 2024).

In the framework of the French research program ASIRIplus-SDS (ANR research program), research on the dynamic behavior of rigid inclusions started in 2020 at the University Gustave Eiffel. In this first phase both experimental and numerical works have been undertaken: the experimental works, due to the selected stiffnesses, concerned more especially the case of rigid inclusions used for the foundation system of a bridge pier. The experimental program focused on the effect of the height of the gravity center of the rigid supported superstructure on the performances of these relatively stiff rigid inclusions combined with a LTP. The analysis was based on comparison with the case of a shallow foundation.

Keywords: rigid inclusion, unconnected pile, piled raft foundation, dynamic soil structure interaction, geotechnical centrifuge, earthquake simulator

2 | Project Objectives

The dynamic response of a rigid inclusion-reinforced foundation represents a complex Soil-Structure Interaction (SSI) problem. Especially in clayey soils, there is still a clear necessity to continue explore the SSI phenomena involved in the response of such foundations under seismic conditions. In this framework the proposed research will focus on the comparison of the performances of rigid inclusions with axial and flexural stiffness in the range of more classical design cases with the unconnected piles and piled raft foundation systems in clayey soils. In this framework a series of centrifuge tests will be designed and performed (70%). Among the objectives, the comparative study will focus on the effect of soil-structure interaction (SSI) on the superstructure frequency, the rocking behavior at the foundation level, the structural response (i.e. structural seismic demand), the foundation settlement and the effect of none linearities of the soil response on the performances of the foundations systems. In collaboration with the Ecole Centrale de Nantes the numerical part will be based on previous works and on the obtained experimental results (30%).

3 | Structure of the research

The program of the thesis is structured into several tasks:

1 – Bibliographic study

The bibliography will focus on the state of the art of the design of the three foundation systems under seismic loadings and the previous experimental and numerical work.

2 – Design of the experimental set up

This task will consist in designing the centrifuge tests. More especially, based on the bibliography, and in relation with practitioners, the reduced scale models of the three foundation systems will be designed taking into account the experimental limitations. In addition, the soil profile, the instrumentation and the experimental procedure of the dynamic centrifuge tests will be detailed.

3 – Experimental program and analysis of the results

The experimental program will be based on the comparison of the dynamic performances of the three foundation systems taking into consideration the dynamic and residual responses of the superstructure such as the induced stresses inside the piles or rigid inclusions. The effect of the soil structure interaction will be based on data processing of localized sensors but also on image analysis. The experimental study, that will consist in 6 centrifuge tests, will provide important proof on the performances of the three types of foundations and will provide a database for numerical modeling.

4 – Numerical modelling

As an effective complement to the experimental work, a numerical work will be made in parallel. A model will be calibrated on the experimental results and also validated. Once validated parametric studies will be done

to analyze the effect of the variation of various parameters to enhance the parameters that have a major effect on the performances of the different types of foundation systems.

4 | Working conditions

In this project, the experimental program will be carried out at the Gustave Eiffel University – Nantes Campus (ex IFSTTAR) within the centrifuge team. This centrifuge is the only equipment for geotechnical application in France, and one of the largest centrifuges in the world (radius 5.5m, 2 tones onboard, maximum acceleration of 100 x g). The geotechnical centrifuge is equipped with an onboard earthquake simulator allowing the application of single (sine) or multi-frequency base shaking in 1 direction with a maximum prototype acceleration of 0.5g. The numerical work will be supervised by professor Panagiotis Kotronis of the Ecole Centrale de Nantes.

5 | Candidate's 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 | Funding

The Ph.D. 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 | 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 .sandra.escoffier@univ-eiffel.fr & luc.thorel@univ-eiffel.fr

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

8 | References

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