Université Gustave Eiffel — LABORATOIRE RRO RISQUE ROCHEUX ET OUVRAGES GÉOTECHNIQUES

Université Gustave Eiffel — LABORATOIRE CG CENTRIFUGEUSES GÉOTECHNIQUES

PhD OPPORTUNITY – RESEARCH IN GEOTECHNICAL EARTHQUAKE ENGINEERING

OPTIMISATION OF SEISMIC DESIGN FOR SOIL-NAILED WALLS

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PhD specialty: Geotechnical Earthquake Engineering

1 | Context

Soil-nailed walls are retaining walls realised through successive excavations and stabilized by long metal inclusions sealed in the ground and called nails. The latter limit the movements of the soil mass thanks to the friction induced by any relative movement between the nail and the soil (Schlosser et al., 1993).

Experimental feedbacks suggest that soil-nailed walls are often overdesigned (Bui et al., 2020) and specifically with regard to seismic loading (Cotton and Luark, 2020). The Loma Prieta earthquake of October 17, 1989 was the subject of a detailed post-seismic study. In particular, nine soil-nailed walls were inspected and demonstrated great resistance (Vucetic et al., 1998). Not only did they not break, but the pull-out tests demonstrated great resistance of the inclusions. Tests carried out in a centrifuge (Vucetic et al., 1998) following these observations confirmed the good earthquake resistance of such structures.

The conservative design of soil-nailed walls can partly be explained by the current practice considering a horizontal acceleration constant over time and uniform over the mass. Indeed, soil-nailed structures, unlike conventional gravity walls, are characterized by great flexibility and a composite nature (soil and inclusions). Not taking this into account leads to an erroneous and overestimated distribution of seismic accelerations, and therefore inertial forces (Yazdandoust, 2017).

However, if overdesign ensures the resistance of the structures to earthquakes, it also prevents any dissipation of seismic energy which is then transmitted to the superstructure. Numerical modeling results point in this direction, indicating that increasing the length of the nails increases the earthquake stability of structures but also increases the head amplification factor (Tavakoli et al., 2019). Generally speaking, in addition to the additional costs generated, the overdesign of geotechnical structures can be the cause of disasters in their immediate environment. Conversely, a less resistant structure can undergo irreversible displacement, thus dissipating a significant part of the seismic energy (Luong, 1999) and allowing the superstructure to remain in the elastic domain; the structure then plays the role of a "geotechnical fuse" (Gazetas, 2015). In order to improve the resilience of territories in the face of seismic risk, it is necessary to rethink the design of geotechnical structures beyond the simple criterion of robustness in order to take into account the safety of the structures they support.

Keywords: soil-nailed walls, earthquake, centrifuge modelling, finite elements, yield design

2 | Project Objectives

In this context, the scientific objective of the thesis presented here is to propose a more optimal earthquake design method for soil-nailed walls. In order to achieve this objective, it is proposed to carry out a study of the seismic behavior of soil-nailed walls combining centrifuge modelling, yield design and finite element method.

3 | Structure of the research and working conditions

Modelling geotechnical structures on a reduced scale in a centrifuge makes it possible to place them in a macro-gravity field and therefore to generate on these models the same states of stress as on the corresponding prototype structures (at scale 1). Gustave Eiffel University has a centrifuge equipped with an on-board 1D earthquake simulator. The experimental protocol and instrumentation must make it possible to measure the forces in the nails as well as the distribution of accelerations in the soil mass. These data will make it possible to characterize the geotechnical fuse effect associated with soil-nailed walls and to calibrate the digital models produced in the thesis.

Dynamic finite element modelling of geotechnical structures is now widely developed. The main obstacle lies in the choice of the constitutive laws used. In the case of soil nailing, the modelling results are strongly dependent on taking into account the non-linearity of the interface behaviour between soil and nail (Gazetas et al., 2004). The experimental determination of this non-linear law is the subject of a PhD thesis in progress at the RRO laboratory. The challenge for the doctoral student will be to integrate this non-linearity into a finite element model.

Yield design theory is based on the static equilibrium of the structure, it has thus mainly been used to study static or pseudo-static problems. A first dynamic approach was developed for the analysis of the bearing capacity of a foundation by Pecker and Salençon (1991). It aims to find an upper bound to the critical acceleration, treated as a volume force. To go further, Dormieux et al. (1992) proposed integrating the displacements due to seismic stress by moving from a yield design model to an elastoplastic model. The thesis will aim to go further in this dynamic approach in the framework of yield design and to apply it to the case of soil-nailed walls. To do this, it will be necessary to specify the dynamic strength criterion to be considered in the soil and the nails and to construct relevant failure mechanisms in the structure.

The work will be divided into 3 periods:

- An initial period of 6 to 8 months dedicated to the literature review and the pre-design of experimental tests using a finite element model.

- A period of at least one year, taking place in Nantes and dedicated to carrying out and analysing centrifuge tests, with a view to feeding the numerical models.

- The final period, devoted to the implementation of numerical models, their validation with regard to experimental tests and their analysis.

The thesis work will give rise to academic recognition in the form of publications in international journals and communications in national and international conferences. A synthesis of the observations made will also feed into the engineering methods used today in the seismic justification of reinforced soil retaining walls.

4 | Candidate's profile

The applicant must have solid knowledge in soil mechanics or continuum mechanics, an attraction to numerical modelling and experimentation, as well as good interpersonal skills and a taste for teamwork, given the numerous interactions envisaged.

5 | 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.

6 | 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 jean.de-sauvage@univ-eiffel.fr & Sandra.escoffier@univ-eiffel.fr

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

7 | References

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