PhD position in computational Civil and Environmental Engineering

Location: Université Paris-Saclay, France

Project description

The PhD candidate will be part of a team of 5 other PhD candidates and post-doctoral researchers to conduct research and develop efficient computational models of Civil Engineering assets in the framework of the project MINERVE.

The project MINERVE is about designing and developing numerical methods and tools for modeling the French rail infrastructure all over its life cycle. MINERVE is leading the ongoing transition towards designing, constructing, operating, maintaining, and decommissioning rail infrastructure assets in a way that is more efficient, more reliable, and with limited negative impact on the environment. MINERVE is improving the global performance of the national rail infrastructure by adapting it to the effects of climate change and by reducing its negative impacts on the planet while increasing its competitiveness.

The project MINERVE gathers 4 industrial partners (SNCF, RATP, Colas Rail, and Kayrros), 1 private research institute (IREX), and 1 academic institution (Université Paris-Saclay). It is financially supported by the French government in the framework of the Recovery Plan and of the Investing for the Future program.

PhD description

Title: Efficient computational approaches for designing new reinforced concrete rail bridges with reduced environmental impact

Keywords: life cycle, finite element analysis, uncertainty, hazard, optimization, reinforced concrete, BIM, structural mechanics.

Supervisors: Fabrice Gatuingt, Pierre Jehel

The design of a rail bridge is an increasingly complex process where various constraints and uncertainties need to be integrated. Specifications are given in terms of geometrical and material properties but also in terms of a given level of performance to be guaranteed during a given period. Performance can be about structural safety, environmental impact, construction and maintenance costs, end-user satisfaction, and so on. Also, rail infrastructure assets need to comply with specific design standards.

For a designer, it is therefore necessary to explore various design scenarios and to assess and convey the performance of each of them. This allows for comparing scenarios and eventually for selecting the best of them. Considering the high dimension of the problem, the designer needs to communicate with other stakeholders to validate and possibly update the space of possible scenarios to be explored. The designer also needs to be assisted by computation tools to build the space of solutions where the best scenario is to be sought.

The general objective of this PhD is to develop efficient computational methods for designing reinforced concrete rail bridges with reduced environmental impact. To achieve this, 3 main steps have to be implemented:

1. Modeling the space of the design scenarios. A BIM (Building Information Modeling) platform is being developed to serve as common data environment for effective and continuous communication with the stakeholders [1]. From the data available in the BIM, uncertainties in the geometry, material properties, boundary conditions, service and environmental loads need to be modeled.
2. Modeling the performance of a rail bridge for a large number of scenarios. An efficient computational methodology needs to be developed and implemented for mapping the space of the design scenarios to the space of the asset performances. Performance features need to be defined (€, CO_2, probability of failure…).
3. Optimizing the design. Computational approaches need to be developed to define the design that will provide the asset with the best performance.

There are a few challenges to be addressed for eventually being able to explore as many design scenarios as possible in a limited amount of time and to assess the performance of a reinforced concrete rail bridge with good accuracy.

Indeed, because of the uncertainty in the design parameters, the dimension of the space of design scenarios is high. Also, the computational structural model that maps a design scenario to the performance of a rail bridge is time-consuming. And finally, the dimension of the space of the asset performances can be large too, depending on how performance is defined. Consequently, efficient sampling strategies combined with meta-modeling and variance reduction in the performance space need to be developed. Methods like importance sampling, active learning [2], sensitivity analysis, multi-fidelity models, will be considered among others.

Another challenge comes from the uncertainty in the evolution of the structural parameters and of the service and environmental loads throughout the life cycle of the asset. Materials long-term characteristics and potentials along with material aging effects need to be quantified and incorporated in the simulations. Besides, natural hazards need to be re-assessed over the years, especially because of the effects of climate change [3]. Methods like multi-fidelity data fusion could be investigated to define instrumentation strategies and monitor the features of the asset [4].

References

[1] S.A. Argyroudis, S.A. Mitoulis, E. Chatzi, J.W. Baker, I. Brilakis, K. Gkoumas, M. Vousdoukas, W. Hynes, S. Carluccio, O. Keou, D.M. Frangopol, I. Linkov (2022) Digital technologies can enhance global climate resilience of critical infrastructure, *Climate Risk Management* **35:** 100387 doi: https://doi.org/10.1016/j.crm.2021.100387

[2] M. Moustapha, S. Marelli, B. Sudret (2022) Active learning for structural reliability: Survey, general framework and benchmark, *Structural Safety* **96**: 102174
doi: https://doi.org/10.1016/j.strusafe.2021.102174

[3] E.J. Palin, I. Stipanovic Oslakovic, K. Gavin, A. Quinn (2021) Implications of climate change for railway infrastructure, WIREs Climate Change; 12:e728
doi: https://doi.org/10.1002/wcc.728

[4] A. Feldstein, D. Lazzara, N. Princen, K. Willcox (2020) Multifidelity Data Fusion with Application to Blended-Wing-Body Multidisciplinary Analysis Under Uncertainty. *AIAA Journal* **58**(2): 889-906 doi: https://doi.org/10.2514/1.J058388

Conditions of employment

3-year contract
???? EUR / month

Workplace

The PhD candidate will be appointed in the Laboratoire de Mécanique Paris-Saclay (LMPS) at Université Paris-Saclay. The LMPS (UMR 9026, Université Paris-Saclay / CentraleSupélec / ENS Paris-Saclay / CNRS) is dedicated to research on all aspects of solid mechanics (mechanics of materials and structures, civil engineering, fine experimentation, and efficient numerical modeling). The LMPS has about 220 members, including 110 PhD students and postdocs and 35 engineers, technicians and administrative staff on two sites of Paris-Saclay University: CentraleSupélec and ENS Paris-Saclay, both in Gif-sur-Yvette. The LMPS hosts four research teams. COMMET: Behaviour of Materials, Modeling, Experimentation and Theory; STAN: Science and Advanced Techniques in Computational Mechanics; MILA: Architectured Materials; OMEIR: Structures, Materials, Environment: Interactions and Risks.

The PhD candidate will join the OMEIR team. The team contributes to the energy, ecological, and digital transitions of all fields related to cities and infrastructures. It brings together the expertise of research groups specializing in construction and natural materials, the modeling of various physical phenomena (mechanical, thermal, hydric, chemical), advanced experimentation, natural risks, large-scale and advanced numerical simulations, and statistical learning.

The associated societal issues in the field of construction in the broadest sense (building, structures, public works, civil engineering, etc.) highlight essential questions related to the ecological and social impacts of human activities concerning not only the resilience of society, but also those associated with information technologies which are disrupting the practices of the sector. In this respect, three important points can be highlighted: the reduction of the ecological footprints of structures; the evaluation and reduction of the vulnerability of constructions (with economic and human impact) subject to hazards/risks, natural or otherwise; the transition from digital models to true digital twins combining multi-physics simulation, data assimilation, and advanced experiments.

Your profile

Master degree in Civil or Mechanical Engineering with skills in:

- Numerical simulation tools: Finite Element theory, Non-linear material behavior laws…
- Structural mechanics and structural design
- Programming languages: Python, Matlab…

Experience with the following would be a plus:

- Design and simulation software: Ansys, Abaqus, Revit, ArchiCAD.

We are looking for highly motivated candidates who are self-driven, have excellent communication and writing skills (fluent spoken and written in English or French is mandatory), and enjoy working in an interactive environment with other PhD students, junior and senior researchers, and industrial and institutional partners.

How to apply?

We look forward to receiving your application with the following documents:

- Application letter explaining why you think you fit in the position
- Detailed CV
- 1 or 2 recommendation letters

Please email your complete application to:

- fabrice.gatuingt@ens-paris-saclay.fr
- pierre.jehel@centralesupelec.fr