Propagation of ground-borne vibrations induced by railways during the exploitation of underground tunnels

3 years (CDD) – October 2022-2025 (financed by ANR E-PILOT project)

1. Description of the Phd

In densely populated areas there is a lack of available area for infrastructure development. This causes problems when the capacity on roads and railways has to be increased. A common solution is to build new roads and railways underground. One example of such a development in France is the Grand Paris Metropolis (MGP) project which officially started in 2010 with the objective to pool together all the resources from its territories to face major society challenges (people and goods mobility, development of economic activity and infrastructures, energy transition) and climate changes. The public Grand Paris Society (SGP) will be in charge for the construction of 200 km of railway lines and 68 new stations for the Grand Paris Express network.

Many researches were devoted to understand possible effects on foundations of the existing buildings and structures in terms of settlements induced during the excavation and on potential significant vibrations in buildings caused by moving underground trains (ANR Tulip and E-PILOT projects). In literature, models for train-induced vibration are presented (Hung H. and Yang Y. B, 2001). These models range in complexity from simple models (including single-degree-of-freedom) to comprehensive three-dimensional models based on numerical techniques such as FEM, BEM or coupled models of these latters. Three-dimensional numerical models are developed by some researchers but they are computationally expensive when assessing vibrations within extended domains, also because of the important range of frequencies to be solved (up to about 100Hz; Sheng, 2019).

The objective of this thesis proposition is to assess the impact of vibrations emitted during the operation phase of tunnels in terms of induced particle velocity trends as function of the distance to the source within homogeneous and heterogeneous 2D and 2.5D domains. Two numerical approaches (discontinuous FEM and DFM) will be adopted. Modeling of ground-borne vibrations will be carried out by incorporating the properties related to the solicitation and the defined configurations (frequency content, spatial extent of the source, stratification, and soil properties). Various configurations will be selected considering the presence of shallow foundations and piles in order to study various network configurations in terms of depths of tunnels, typologies of trains and speed, and mechanical and geometrical properties related to the lithology encountered along the Grand Paris Express path. Indicators characterizing horizontally stratified configurations will be introduced based on wave velocity in the different layers and other parameters. Equivalent homogenized configurations will be associated with the stratified configurations based on these indicators. Differences in vibration responses between homogeneous and heterogeneous cases will be analyzed in order to define

correction factors depending on the introduced stratigraphic indicators. The domains will be defined to represent the propagation over a distance of about 200 m far away from the traffic source and considering synthetic signals and measurements recorded near the underground tracks and/or along the surface. To sum up, the work will be articulated in 3 phases: 1) the realization of a parametric study for various configurations in order to obtain transfer functions by the use of impulsive functions, 2) the utilization of these transfer functions to recombine the solution for more realistic solicitations by the means of procedures of superposition of induced effects and 3) a validation of the procedure of recombination by comparison with field observations, the latter being available in the framework of the on-going ANR E-PILOT project.

References

Hung H.and Yang Y.B. (2001). A review of researches on ground-borne vibrations with emphasis on those induced by trains. Proc. Natl. Sci. Counc, 2001, 25(1), pp. 1-16.

Sheng X. 2019. A review on modelling ground vibrations generated by underground trains, International Journal of Rail Transportation, DOI:10.1080/23248378.2019.1591312.

2. Required skills

Strong engineering geotechnical skills are required. These include essential knowledge of:

- Soil mechanics and dynamic behavior of soils in saturated and unsaturated soils
- Wave propagation in complex media (elasticity, viscoelasticity theories)
- Numerical modelling (FEM, DFM, BEM)
- Signal processing and Statistics

The student should be familiar with programming languages such as Matlab or Python.

The knowledge of FLAC Itasca code is welcome.

3. Hosting conditions for the thesis project

- The doctoral student will be employed by Cerema on a doctoral contract from fall 2022 to fall 2025 (exact dates to be determined with the doctoral student)
- The remuneration will be about 1500€ the first two years and 1700€ the third
- The project will take place mainly in Cerema in Sophia-Antipolis

  CEREMA Méditerranée
  500 route des Lucioles
  CS 80125 Valbonne
  06903 Sophia-Antipolis cedex

- The PhD student will benefit from the training of the doctoral school of registration.

4. Supervision team of the thesis project

- The PhD student will be hosted in the REPSODY team of Cerema (DterMed), whose leader is Luca Lenti.

- The project will be supervised by PhD Luca LENTI, Research Director and Chief of REPSODY/Cerema, Sophia Antipolis, as Thesis Director.
- The project will be supervised by PhD Etienne BERTRAND, Research Director, University Gustave Eiffel, Champs sur Marne, as thesis co-director
- The project will be co-supervised by Nathalie GLINSKY (Cerema, DterMed, REPSODY) and by Céline BOURDEAU researcher at the University Gustave Eiffel, Champs sur Marne.

5. Contact for application

The interested candidate is invited to contact as soon as possible the Cerema supervisor of this project:

Luca LENTI, CEREMA Méditerranée
500 route des Lucioles
CS 80125 Valbonne
06903 Sophia-Antipolis cedex

luca.lenti@cerema.fr
Tel .04 97 28 86 44

6. Documents demanded to apply

- The candidate's CV
- A copy of his/her identity card or passport
- The marks of the master (at least the master 1 if the marks of the master 2 are not available)
- A copy of the last diploma (master's degree, engineering degree, research master's degree if already defended)
- A letter of motivation from the candidate explaining his or her interest in the subject (maximum 1 double-sided page)
- A letter of recommendation

The candidate should send a complete file (above elements gathered in a single .pdf file), by e-mail, before end of June 2022.