PhD Position Opening:

Applications of Artificial Intelligence for deciphering strength development of binder-soil mixtures in the context of soil stabilization

In the context of increasing concern in Environment protection and decarbonation of engineering processes, soil improvement methods using binder (cement, lime, or any combination of both with other products) addition during the compaction can help increase the use of locally extracted materials in construction projects. For instance, in France, more than 10 million tons of excavated geomaterials are deposited every year due to their “poor” mechanical or hydraulic performance [1] while virgin soil/rock are becoming less and less available and their use involves growing environmental and financial transportation costs. The addition of a binder to the soil sets up a series of chemical interacting mechanisms (cement hydration, pozzolanic reaction, carbonation, and suction development). These processes lead to an improvement of the mechanical properties (strength and deformation moduli) allowing to upgrade the material from a waste to a resource. The mechanical performance of the soil treatment is mainly controlled by several parameters namely: the amount of binder added, the compaction conditions, and the curing conditions. In the literature, different studies have investigated the key-parameters controlling the strength development in treated soils [2-5]. However, the complexity of the involved mechanisms, and their interdependency are still considered as a scientific challenge to permit a mastered use of binder-treatment for soil stabilization. Practitioners need more insight on the long-term evolution of the stabilized soils’ performance since engineering structures are supposed to have a +50-year life span. The reliable prediction since the early design stage, of the time-dependent performance considering the different environmental solicitations (e.g. wetting-drying and freeze-thaw cycles) to which the engineering structure will be submitted, is of primary concern.

In the recent developments, Artificial Intelligence (AI) and Machine Learning (ML) techniques, have arisen as a promising means in various scientific domains including some applications in geotechnical engineering. The increasing quantity and quality of the data available offer new possibilities to handle complex problems covering clustering, classification, and regression problems. Recently, attempts were made to use ML regression methods that do not require the knowledge of the predictors-targets relationships and use data to train the model. Gajurel et al. (2021) investigated the use of several ML regression techniques for predicting the reference Unconfined Compressive Strength of stabilized soils from common geotechnical properties and binder type and amount [6]. Up to our knowledge, no attempts have been made to use advanced AI/ML methods as Artificial Neural Networks (ANN) for predicting the post-curing behavior of stabilized soils although many authors set up comprehensive databases from extensive laboratory experiments.

The LEMTA’s soil mechanics research team developed over the past two decades a thorough knowledge concerning the stabilized soils’ behavior with outstanding laboratory equipment (https://lemta.univ-lorraine.fr/mecanique-des-sols-2/) [7-11]. A considerable database has been constructed including experimental data from different geotechnical tests (UCS, triaxial and shear box, oedometer, permeability…). An extensive testing program is currently running to investigate the impact of multiple wetting-drying cycles on the mechanical performance to explore the treatment durability issue.

The PhD objectives can be summarized by: (i) optimizing the database structure to make it appropriate for generating the training, testing and validation datasets for AI/ML models; (ii) perform statistical data analysis to give insight of the correlations and tendencies for selecting the best candidate predictors from the datasets; (iii) using AI techniques (including ANN and Deep Learning) to develop predictive models for post-curing properties including long-term behavior and (iv) develop and validate data-driven design tools for engineering practice.

Candidate qualifications:

The candidate must hold a Master's degree with a background in Applied Mathematics & Statistics or a background in Civil-Geotechnical Engineering and a keen interest in a keen interest in AI. Mastering Python and/or Matlab programming is required.

Contact information:

Supervisor: Prof. Olivier CUISINIER, olivier.cuisinier@univ-lorraine.fr
Co-supervisor: Dr. Adel ABDALLAH, adel.abdallah@univ-lorraine.fr

Work conditions:

Net salary≈1400 €
Work languages: English, French
This work is part of a project funded by the European Union, the GeoRES project (ID: 778120): http://emps.exeter.ac.uk/engineering/research/computational-geomechanics/geores/. The doctoral student will be required to collaborate with the other partners of the project.

Application:

Application by email should include:
- a CV
- a copy of the Master's thesis or a detailed summary of the Master's research project
- transcript records
- 2 academic references contact details

Application:

[1] Hale S.E., Roque A.J., Okkenhaug G., Sørmo E., Lenoir T., Carlsson C., Kupryianchyk D., Flyhammar P., Žlender B., 2021. The Reuse of Excavated Soils from Construction and Demolition Projects: Limitations and Possibilities. Sustainability, 13, 6083. https://doi.org/10.3390/su13116083

[2] Cuisinier O., Auriol J.-C., Le Borgne T., Deneele D., 2011. Microstructure and hydraulic conductivity of a compacted lime-treated soil, Eng Geol, 123:187–193, https://doi.org/10.1016/j.enggeo.2011.07.010

[3] Russo G., Modoni G., 2013. Fabric changes induced by lime addition on a compacted alluvial soil, Géotechnique Letters 3:93–97, https://doi.org/10.1680/geolett.13.026

[4] Soltani A., Deng A. , Taheri A., irzababaei M., Jaksa M.B., 2020. A dimensional description of the unconfined compressive strength of artificially cemented fine-grained soils, J Adhes Sci Technol 34:1679–1703, https://doi.org/10.1080/01694243.2020.1717804

[5] Williamson S., Cortes D.D., 2014. Dimensional analysis of soil–cement mixture performance, Géotechnique Letters 4:33–38, https://doi.org/10.1680/geolett.13.00082

[6] Gajurel A., Chittoori B., Mukherjee P.S., Sadegh M., 2021. Machine learning methods to map stabilizer effectiveness based on common soil properties, Transportation Geotechnics, Volume 27, ISSN 2214-3912, https://doi.org/10.1016/j.trgeo.2020.100506

[7] Menaceur, H. Cuisinier, O. Masrouri, F. Elsami, H. 2021. Impact of monotonic and cyclic suction variation on the thermal properties of a stabilized compacted silty soil. Transportation Geotechnics. 28, 100515.

[8] Cuisinier, O., Masrouri, F., Mehenni, A., 2020. Alteration of the hydro-mechanical performances of a stabilised compacted soil exposed to successive wetting-drying cycles. Journal of Materials in Civil Engineering, 32 (11), 04020349.
[9] Kaddouri, K., Cuisinier, O. & Masrouri, F. 2019. Influence of effective stress and temperature on the creep behavior of a saturated compacted clayey soil. Geomechanics for Energy and the Environment 17, 106-114.
[10] Mehenni, A., Cuisinier, O. & Masrouri, F. 2016. Impact of lime, cement and clay treatments on the internal erosion of compacted soils. Journal of Materials in Civil Engineering, 28.
[11] Blanck, G., Cuisinier, O. & Masrouri, F. 2016. Life cycle assessment of non-traditional treatments for the valorisation of dry soils in earthworks. International Journal of Life Cycle Assessment, 21, 1035–1048.