ENAC – School of Architecture, Civil and Environmental Engineering
SGC – Civil Engineering Section
LMS – Soil Mechanics Laboratory
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Pre-study and Master Thesis
Fall Semester 2023

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Thermo-hydro-mechanical analysis of a novel offset pipe configuration within a helical steel energy pile

Supervisor: Professor Lyesse Laloui
Assistant : Dr. Elena Ravera

Motivation of the project

The practice of using foundation elements to meet the energy needs of buildings started in Austria and Switzerland with the use of base slabs in 1980, piles in 1984, diaphragm walls in 1996 and energy tunnels at the beginning of 2000. In the UK, the practice of installing energy piles started in early 2000, with about 6219 piles installed in 2019 providing annual carbon dioxide savings of about 7753 t. Since 2016, at least 5289 piles have been installed in Switzerland based on available data from the country's largest manufacturers. The most used material in pile construction is reinforced concrete, however, there are also applications with steel piles. This study focuses on a novel offset pipe configuration within a helical steel energy pile. A helical steel pile is a hollow casing with a welded screw and a tip that allows it to be drilled into the ground. The present system uses two offset pipes which are disconnected within the large volume of water in the steel casing. Essentially, the water will be channeled into the pile through a long inlet pipe, up through the cavity and then out through an offset outlet pipe. Heat exchange takes place between the working fluid, the surrounding steel wall, and the ground domains to achieve the temperature change required for heat pump operation.

The objective of this study is to model the thermo-hydro-mechanical behavior of the helical steel energy pile. The modelling will be based on thermo-hydraulic simulations representing real fluid flow in non-isothermal conditions and heat transfer processes by conduction and convention. The effects of operation on the mechanical behavior will be simulated considering the thermomechanical interactions and the interactions between the fluid and the structure. The analyses should be performed to identify the dominant parameters on the performance of the system. The final output should include guidelines that may be used for engineers when dealing in practice with such technology.

Keywords

Helical steel energy pile, fluid dynamics, geothermal energy, ground shallow heat pump, heat transfer, Finite element analyses (COMSOL Multiphysics), renewable energy

References

Nicholson, S. R., Kober, L. R., Atefrad, P., Mwesigye, A., & Dworkin, S. B. (2021). The influence of geometry on the performance of a helical steel pile as a geo-exchange system. Renewable Energy, 172, 714-727.
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Nicholson, S. R. (2020). Characterization of a novel in-ground heat exchanger for applications in sustainable building energy and maintaining permafrost. Master Thesis, Ryerson University Toronto (Canada).

Goal of the project

By the end of the project, the student is expected to be able to:

- Model an analyze the thermo-hydro-mechanical behavior of a helical steel energy pile
- Identify the dominant parameters on the performance of the novel energy system
- Provide guidelines when dealing in practice with such technology
- Critically assess and present the results

Tasks and work to carry out

- Literature review
- Building the numerical model
- Validation of the numerical model with available data from literature
- Thermo-hydro-mechanical analyses
- Representation of the results in a consistent and effective manner
- Compose a project report in written form
- Presenting a project orally

Deliverables

- Report

The student will have to prepare a technical report containing the introduction and motivation for the project, the description of the accomplished work and related results as well as conclusions. The technical report will have to be prepared in an electronic format and send to the supervisor and the responsible of the project by the end of the semester.

- Final Presentation

The student will have to present his work during a presentation at the end of the semester. The day and the place of the presentation will be communicated to the student.

Planning

- Meetings and presentations

A weekly meeting (on Friday pm) with the assistant is suggested to discuss the progress of the project. One meeting per month will be organised with Prof. Laloui (dates will be communicated to the student). During the meetings with the assistant, the student will have to present (i) the progress of the work, (ii) possible questions and remarks and (iii) a summary of the next steps for the project. During these meetings, the supervisors may vary the foreseen goals of the project, if necessary. The student will have to prepare all the possible questions before the meeting in written form and a summary of each meeting for the next fixed meeting.

- Report

The report will be written in English. Graphs will be built with the Grapher software, Matlab, or with the aid of Microsoft Excel. Particular attention will be given to the writing up of the report. In the

document, the student will have to clearly introduce the topic, to highlight the hypotheses made, to present the considered methodology, to discuss the obtained results and to draw the related conclusions.

- **Electronic files**

At the end of the project, the student will have to send to the supervisors a folder containing a clear classification of all the electronic files developed during the project, including those related to the reports, obtained data, presentations, poster and graphs.

Grading

The final grade will be assigned considering the following proportions of contribution:

- Technical report 70%
- Oral presentation 30%

The evaluation will also consider the work methodology, discipline and resourcefulness of the student.

General rules of the project

The schedule of the project is defined by the EPFL Academic Calendar:
https://memento.epfl.ch/academic-calendar/?period=180

The student signature on the submitted report certifies that the work is original and developed by him/herself. This work is property of the EPFL and cannot be disseminated without the approval of the considered Institution.

Contacts

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