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Cutter Soil Mix-Energywall full-scale test experimental setup

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The demand for sustainable heat production is growing worldwide [1]. Classical geothermal borehole installations are costly due to the required boring depth and space demands in the urban environment. Shallow geothermal heat exchangers comprised of thermally-activated geostructures in combination with heat pumps (also known as energy geostructures, EGS) offer an interesting alternative due to a combination of functions [2].

This paper focuses on the thermal properties of the CSM (Cutter-Soil-Mix [3]) Energywall; a novel EGS type in which heat exchanger pipes are installed in a cutter-soil-mix wall to thermally activate it. Therefore, the CSM Energywall serves the dual function of supporting the soil/overlying structure and providing geothermal energy for space heating/cooling. A test site has been setup in Amstelveen, the Netherlands, where this system will be tested for a 1 year period (starting March 2023). A test site picture is shown in Figure 1.The goals of the experiment are to evaluate the thermal efficiency of the system and to assess its thermo-mechanical behaviour by means of numerical models valiated against the data collected from site monitoring. In the first part of the forthcoming paper, test setup and experimental results (both from the field and laboratory tests of the CSM material) will be presented. In the second part, the implementation and validation of the numerical models will be described. Lastly, the paper will focus on the suitability of the CSM-Energywall as a sustainable urban heat source, with particular reference to the Netherlands context.

Figure 1: CSM-energywall test site (left), activation loops attached to the steel colums (middle), schematization (right)

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The following research questions have been defined for the CSM-Energywall experiments:

- What is the heat extraction potential of a CSM-Energywall in sandy and in cohesive soils?
- Does thermal activation affect the mechanical properties of the CSM material?
- What is the long term heat production potential of the CSM-Energywall?
- How accurately can the heat extraction potential be predicted using numerical models?

A test setup at Amstelveen (NL) has been built to answer the above research questions. The test site is located in a building pit of 22 x 13m. CSM-walls were built along the pit perimeter, serving both as a soil retaining structure and as a foundation for the superstructure. The CSM wall has a thickness of 0.55m and is reinforced with IPE steel beams. The bottom of the CSM wall has a level of NAP-18.0m (NAP= Normaal Amsterdamse Peil, vertical reference system of the Netherlands). The bottom of the steel IPE beams is at a level of NAP-15.6m. The ground level at the test site is located at NAP-0.7m and the groundwater table at NAP-1.5m. The building pit has an excavation level of NAP-4.70m. Heat exchanger pipe loops with a diameter of 20mm have been connected to the steel beams representing the CSM wall reinforcement (Figure 1). The loops have a depth of NAP-15.0m or NAP-11.0m. Five main groups of loops are connected to the flow distributer. Each group is then split into six subgroups. Each subgroup consists of two thermoactive steel rebars. The test setup will run for the duration of the building construction. Being able to select the geothermal activation of the shallowest or deepest loops, it will be possible to measure the energy output of both the fine-grained layers (with a bottom depth of NAP-11.0m) and the underlying sandy layers.

During the tests the following aspects will be monitored:

- Flowrate of fluid through the main loops (FTB4700 Flowmeter)
- Temperature of each main group of loops (PT100 thermowell)
- Flowrate and temperature of heat pump inlet/outlet fluid (Kramstrup Energymeter)
- Temperature of the soil (thermistor strings)

CSM material core samples have been taken for laboratory testing. Cyclic thermal loading, unconfined compression strength (UCS) tests, computerize tomography (CT) scan tests and hot disk tests will be conducted on samples taken from different depths. The goal of the laboratory testing is to evaluate:

- The thermal properties of CSM material depending on the original insitu soil composition, needed to assess the thermal efficiency of the system.
- The UCS of the CSM material, and its possible dependency on temperature.
- The macroporisy and density distribution of the CSM material, to gain insight into the material composition.
- The influence of thermal cycling on the material's mesostructure (e.g. porosity and density distribution).

The full-scale experiment is going to be numerically modelled in 3D using the COMSOL Multiphysics Finite Element software. The model will be validated based on the experimental results of the test after 1 year and calibrated using laboratory measured thermal properties of the CSM material. The model will then be extended to predict the long term efficiency of the CSM- Energywall and its thermo-mechanincal behaviour.

Contributor statement

Leclercq. V: Conceptualization, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Project Administration, resources; Gerola. M.: Conceptualization, Formal analysis, Writing – review & editing; de Jong F.K.: Conceptualization, Writing – review & editing. Cecinato F.: Conceptualization, Writing – review & editing. De Kok, O. Conceptualization, , Writing – review & editing;

References

[1] Loveridge, F., McCartney, J. S., Narsilio, G. A., & Sanchez, M. (2020). Energy geostructures: A review of analysis approaches, in situ testing and model scale experiments. Geomechanics for Energy and the Environment, 22. https://doi.org/10.1016/j.gete.2019.100173

[2] Brandl, H. (2006). Energy foundations and other thermo-active ground structures. Geotechnique, 56(2), 81–122. https://doi.org/10.1680/geot.2006.56.2.81

[3] Fiorotto, R., Schöpf, M., Stötzer, E. (2005). Cutter Soil Mixing (C.S.M.) An innovation in soil mixing for creating cut-off and retaining walls. Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering, pp. 1185 – 1188. doi:10.3233/978-1-61499-656-9-1185