Experimental and numerical characterization of the thermo-mechanical behavior of quadratic cross section energy piles

The Danish government has set two main targets: a 40% reduction in greenhouse gas emissions by the year 2020 relative to 1990 and to cover the total domestic energy consumption by renewable energy sources by 2050. In combination with other renewable energies, shallow geothermal energy storage (heating and cooling supply) and utilization has a great potential for realizing the transition from fossil fuels to renewable energy sources.

In the 1980’s, a new alternative to traditional borehole heat exchangers, in form of energy foundation piles, was developed by the construction industry. Energy piles are thermo-active ground structures that utilize reinforced concrete foundation piles as vertical closed-loop heat exchangers.

From a commercial point of view, potential customers are reluctant to purchase the technology due to a lack of documentation of the long-term structural and thermal performance of energy foundations. To address these concerns it is necessary to understand the performance of the soil-energy pile interface under cyclic thermal loads in the long-term and its potential influence on the energy supply. The characterization of the soil-pile interaction is vital for the design of energy pile foundations as it affects the bearing capacity. The existing design standards do not consider the nature of thermo-active foundations and, in general, too conservative considerations are employed in the design of energy pile foundations.

So far, the thermal dimensioning of thermo-active foundations is based on the standards for vertical ground source heat pump systems. However, some thermally active geostructures do not fulfil the basic valid assumptions for vertical heat exchangers due to different aspect ratios (length/diameter) and cross section geometries. Therefore, novel approaches that better characterize the heat transfer in and around such structures are required.

The present Industrial PhD project is carried out by the Danish company Centrum Pæle A/S (Vejle), who produces precast foundation piles: The academic participants are the Civil Engineering Department at Aalborg University and VIA University College.

The PhD project has overlapping scientific and commercial perspectives: 1) characterize the thermal behaviour of the pile which has to be optimized with respect to storage and abstraction of heat from the ground. 2) Characterize the geotechnical performance of the pile quantifying the thermal loads added to the structural actions due to the geothermal use. This serves to investigate to what extent this thermal loading affects the ultimate and/or the service limit state of the pile. To cover this apparent knowledge gap, experimental and numerical methodologies must be combined.