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DESIGN AND EXECUTION OF ENERGY PILES: VALIDATION BY IN-SITU AND LABORATORY EXPERIMENTS

An energy pile (or thermo-active pile) is an unconventional deep foundation solution that integrates pipe circuits allowing heat exchange between the pile and the surrounding ground. This setup is part of a ground source heat pump system that is conventionally used for heating and/or cooling purpose in buildings. Besides the design related to its energy performance, several national guideline documents recommend various additional considerations for the geotechnical design of thermal piles including: axial and radial pile expansion/contraction/fixity, thermally induced axial stresses, cyclic effects of thermal loading, temperature at soil-pile interface including daily/seasonal variations. Nevertheless, these recommendations are mostly based on empirical data and no definitive design procedure is yet available.

The objective of this thesis is to identify and quantify the principal parameters involved in the geotechnical design of pile foundations impacted by temperature changes associated with geothermal activation. For this purpose, the results from two full scale experimental campaigns are analyzed. An academic setup with controlled loading conditions is first studied. Two 12-m long piles with a nominal diameter of 0.42 m were installed in a site including layers of clay and marl on the grounds of Ecole de Ponts Paris Tech, close to Paris. One of the piles was first loaded to a pile head axial force equal to 600 kN, corresponding to its serviceability capacity. Afterward and for constant pile head load, three thermal cycles were applied to simulate the seasonal thermal loading using a refrigerated and heating circulator. The pile temperature varied between 4 °C and 25 °C (initial value 12.5 °C). The imposed temperature gradient is similar to the annual heating /cooling average temperature variation observed in energy foundations under a typical building operation. The second case study focusses on understanding the behavior of energy piles in a building with a heat pump. Two energy piles and a conventional pile with a length of 10m and a diameter of 0.42m were instrumented with vibrating wire sensors equipped with thermistors during the construction of the pretreatment building of the Sept Sorts water treatment in Seine-et-Marne department, in France. Their behavior under exploitation conditions was recorded and the results are presented.

Furthermore, the impact of temperature and cyclic thermal loading on the soil-pile interface was studied in the laboratory using an interface direct shear device equipped with a temperature control system. The laboratory experimental campaign was divided in three parts: (i) concrete-soil direct shear tests at 13 °C (constant temperature) to be used as a reference, (ii) concrete-soil monotonic displacement controlled direct shear tests at 8°C and 18°C and (iii) concrete-soil displacement controlled direct shear tests after 10 thermal cycles with a gradient Δ T=10°C (8°C-18°C). Finally, numerical simulations with the finite element method were performed to reproduce the results obtained in the Sept Sorts field test and to study the influence of different combinations of thermal and mechanical loads of the behavior of the energy piles.

Mots-clés : pieux énergétiques, cycles de température, interface sol-pieu