Tuesday 3/14/2017

3–4:30 p.m.

Energy Geostructures 1

Chairs: Guney Olgun, Virginia Tech; John McCartney, University of California, San Diego

Investigation of Small-scale CAES (compressed air energy storage) Pile as a Foundation System

Sihyun Kim, and Manideep Tummalapudi, Bradley University; Junyoung Ko and Hoyoung Seo, Texas Tech University; Seunghee Kim, University of Nebraska–Lincoln

Compressed air energy storage (CAES), in which surplus energy is utilized for compressing ambient air that can be released later to provide necessary energy, is being actively pursued in a last decade. This technology has a potential to strengthen the efficiency of renewable energy generation, such as solar and wind power. In addition to the large-scale energy storages, CAES can be operated at a small-scale to support facilities such as residential buildings. In this case, closed-ended steel piles can serve to provide the space where pressurized air is stored during off-peak periods, which leads to an idea of small-scale CAES pile. To continue pursuing the idea of using pile foundation system as an energy storage vessel, we need to examine long-term stability of CAES pile. In this pilot study, we investigate a finite element model of an axisymmetric CAES pile that is subject to the internal uniform pressurization while supporting a constant structural load. Long-term stability of the CAES pile is assessed from the first 10 pressurization-depressurization cycles at the various initial dead load conditions. Elasto-perfectly-plastic constitutive law is employed at the pile-soil interface for simplicity. We are able to observe that vertical displacement of the CAES pile accumulates with negligible radial deformation as the number of pressure cycle increases.

Role of Thermally Induced Buoyant Flow in Altering Energy Harvesting Using Geothermal Piles

Omid Ghasemi Fare, University of Louisville; Prasenjit Basu, Indian Institute of Technology, Bombay

This paper presents a numerical model and its application to analyze thermally induced pore fluid flow in saturated soil surrounding geothermal piles. Coupled effects of heat conduction and convection on thermal performance of heat exchanger piles in saturated soil are considered. Heat transfer energy equation and Brinkman's momentum equation that considers a Boussinesq buoyancy term are coupled to analyze convective heat transfer through pore fluid flow. A hybrid explicit-implicit approach is employed in the finite difference solution scheme to calculate pore fluid velocity and temperature increments within the ground. Results indicate that thermal operation of geothermal piles alters pore fluid density, buoyant flow occurs (even under hydrostatic condition) within saturated soil in the vicinity of heat exchanger piles, and thermally induced pore water flow under saturated condition facilitates pile-soil heat exchange.

Reliability-Based Geotechnical Design of Geothermal Foundations

Lei Wang and Nicholas Smith, Montana Tech of the University of Montana; Sara Khoshnevisan and C. Hsein Juang, Clemson University; Zhe Luo, Tongji University

In recent years, there are applications of geothermal foundation for near surface geothermal energy utilization in geotechnical engineering. However, significant uncertainties exist in design of such foundations and affect the thermal-mechanical behaviors. To consider these uncertainties explicitly, it is desirable to develop a reliability-based design methodology for geothermal foundations by quantifying

the uncertainties in thermal-mechanical soil-structure interaction of the geothermal foundation design. In this paper, the deterministic analysis for geothermal foundation is performed using a numerical model. A series of advanced moment methods are used for assessing the probability of exceedance in terms of both factor of safety and displacement requirements of geothermal foundations by combining the reliability method with the deterministic numerical model. A case study for a geothermal foundation design is presented to demonstrate the significance of the proposed framework for reliability-based design of geothermal foundations.

Response of Suction Caissons in Clay Under Monotonic and Cyclic Horizontal Loading

Jeff F. Wallace and Cassandra J. Rutherford, University of Illinois at Urbana–Champaign

Tidal energy converters (TECs) provide a means to extract energy from the horizontal flow of water resulting from the rise and fall of tides. It is critical that the behavior of all aspects of the TEC, including the foundation, be understood to optimize not only its reliability but also its cost efficiency. Unlike the majority of offshore energy structures that attempt to minimize the interaction with flowing water, a TEC is designed to interact with this flow through a rotating turbine. The rotating turbine blades, fluctuations in the tidal current speed and direction, wave loading, turbulence, and vibrations all result in a combined cyclic loading of the foundation or anchoring system. A suction caisson is a suitable foundation type to secure tidal current turbines to the seabed. In soft marine clays, the suction caisson provides an ideal foundation for TECs that can be installed without the need of equipment for pile driving or mobilizing gravity base foundation while allowing for the removal of the foundation, contributing to the overall “green” nature of the device. When configured in the monopod configuration the TEC will apply significant horizontal loading on the suction caisson. Therefore, the response of a suction caisson in the monopod configuration in soft clay with an aspect ratio of 1 is investigated under monotonic and cyclic horizontal loading.