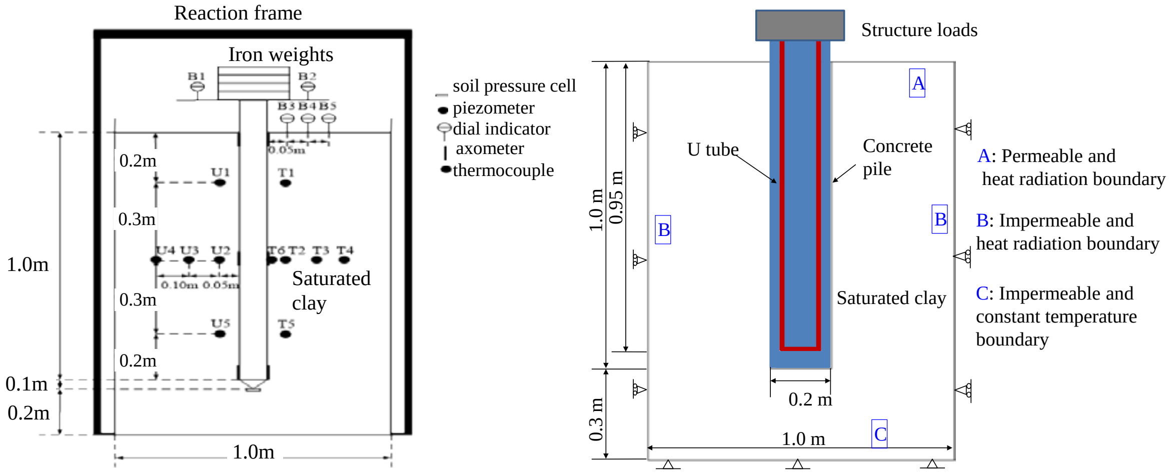
Large scale model tests and numerical investigations on thermo-mechanical behavior of energy pile in saturated clay

Xiaohua Bao[1] *, Hongzhi Cui[1], Yonglin Xiong[2], Ganbin Liu[2], Rongyue Zheng[2]

[1] Department of Civil Engineering, Shenzhen University, Shenzhen, China,
[2] Department of Civil Engineering, Ningbo University, Ningbo, China
* bxh@szu.edu.cn

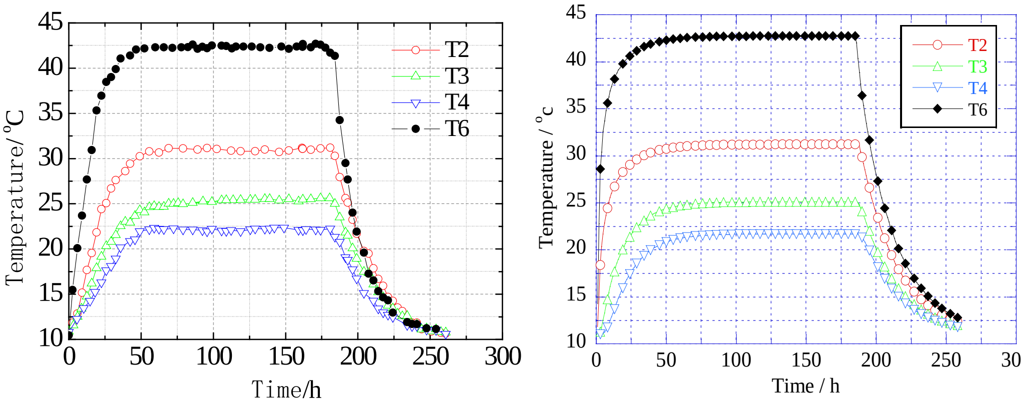
The geothermal use of Energy piles is an environmentally friendly way of cooling and heating buildings (Laloui et al. 2006). One of the problems is that the energy piles used in clay soil under the cyclic thermal loads may undergo long-term accumulated settlements and stability problems due to the complex thermo-mechanical behavior of clay. Studies presented that heating could induce a large pore-water pressure increase, which eventually leads to a large irreversible strain and possible mechanical failure (Hueckel & Pellegrini 1992). The observed creep rate of the energy piles in clay could lead to additional time-dependent displacement of the foundation over the life time of the structure (Akrouch et al. 2014). In this study, an instrumented energy pile model test performed with a 1.1 m in length and 0.2 m in diameter installed in a 1.0 m×1.0 m×1.5 m soil tank filled with saturated clay was conducted. The initial temperature of the soil and pile was set to be 11ºC (atmospheric temperature). Before heating, a dead load of 2 kN (half of the ultimate bearing capacity) was applied on top of the pile to simulate from a superstructure loads. After the excess pore pressure was fully dissipated and the settlement of pile reached a the stable state, the pile was heated by fixing the inlet water flow to a velocity of 0.2 m/s and inlet temperature of 50ºC. After a period of stable state, stop heating and let the pile-soil naturally cooled. The model test was also simulated using the finite element-finite difference (FE-FD) method performed by a thermo-hydro-mechanical (THM) coupling program. The thermal mechanical performance of saturated clay were described by a new thermo-elastoplastic constitutive model that the concept of equivalent stress and subloading surface was adopted to describe the thermal effect and overconsolidated behavior of soil.

Fig.1 presented the schematic diagram of model test and the corresponding numerical model. Fig.2 presented the temperature curves of the soil along a radial direction at the depth of 0.5 m below the soil surface. Fig.3 presented the development of excess pore water pressure (EPWP) at 0.5 m below the soil surface and at a different radial distance from pile side. Fig.4 presented the axial strain distribution along the pile. Fig.5 presented the variation of the vertical displacement at the soil surface at different distances away from pile side during the heating-cooling process.



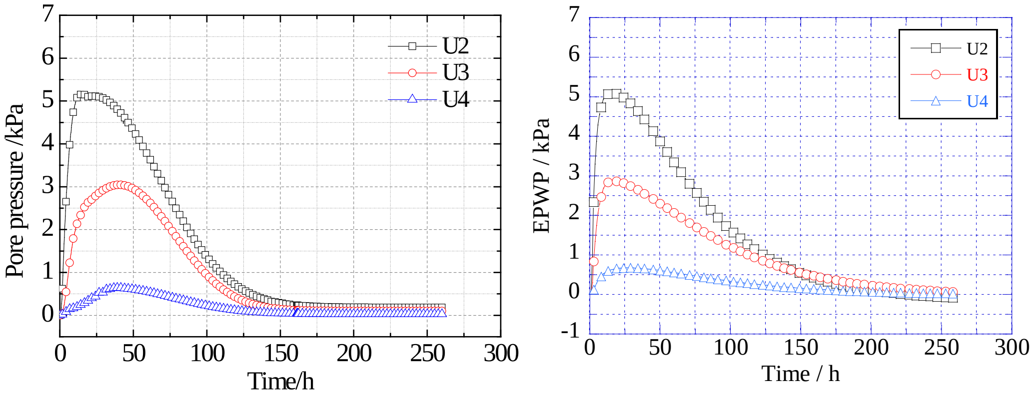
(a) Schematic diagram of model test (b) Numerical model

Fig. 1: Model test and numerical simulation on energy pile in saturated clay.



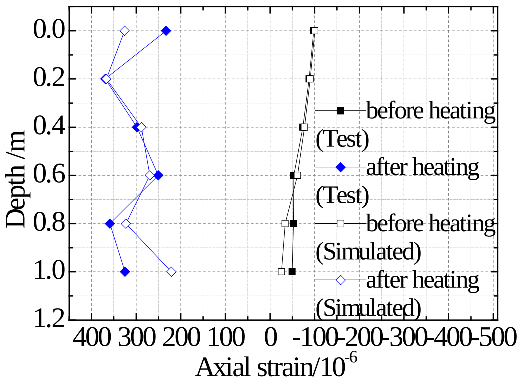
(a) Test (b) Simulation

Fig. 2: Temperature curves of soil along radius at the depth of 0.5 m below soil surface.



(a) Test (b) Simulation

Fig. 3: Time-excess pore pressure curves of soil at different radius distance from pile side.



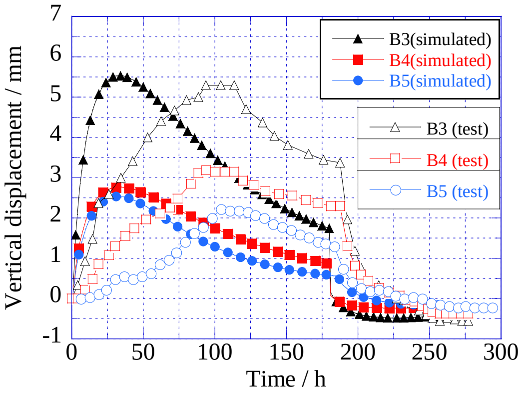


Fig. 4: Axial strain of pile. **Fig. 5:** Time-vertical displacement curves.

References

Akrouch GA, Sanchez M, Briaud JL (2014) Thermo-mechanical behavior of energy piles in high plasticity clays. Acta Geotechnica 9:399-412

Hueckel T, Pellegrini R (1992) Effective stress and water pressure in saturated clays during heating–cooling cycles. Can Geotech J 29:1095–1102

Laloui L, Nuth M, Vulliet L (2006) Experimental and numerical investigations of the behavior of a heat exchanger pile. Int J Numer Anal Methods Geomech 30:763–781