Energy Pile Simulation - an Application of THM-Modeling

E. Holzbecher[1]

[1]Georg-August University, Göttingen, Germany

Abstract

Introduction:
Energy piles, i.e. heat exchangers located within the foundation piles of buildings, are used for heating of cooling purposes (Laloui & di Donna, 2013). Although the absolute values of deformations and temperature gradients are low or moderate, the entire setting can be influenced by thermo-hydro-mechanical coupling. The fluctuating thermal regime may affect the deformation of pile and surrounding ground as effect of mechanical loading. Groundwater flow changes the temperature distribution around the piles and due to pore pressure may also have an effect on the mechanical state of the sub-surface. As the following shows, such process interactions can be investigated by a coupled numerical approach using COMSOL Multiphysics®.

Model Set-up:
A generic model for a single pile and a homogeneous surrounding was published by Bodas Freitas et al. (2013). The 2D model region in an axi-symmetric coordinate system is shown in Figure 1. The upper inner sub-region (green) represents the pile, while the remaining (blue) represents the ground. The pile is loaded at the top. The free surface of the porous medium has atmospheric pressure, while the outer vertical boundary has roller as mechanical condition, no-flow as hydraulic condition and constant temperature as thermal condition.

Results:
For verification of our approach we compare output obtained using solid mechanics approach in COMSOL Multiphysics® with published results. Figures 2 and 3 show the change in pile axial stress and in interface shear due to consideration of thermal expansion. The parameter changed is the thermal expansion factor of the ground. Figure 4 shows the temperature distribution around the pile. The rise of ground surface due to heating and the sinking of the pile into the ground, although hardly visible, are exaggerated. In the paper we extend the model assuming the ground to be poroelastic and not solid, and describe the effect of this assumption.

Conclusion:
Using COMSOL Multiphysics® a model concept is developed that enables the simulation of coupled mechanical, hydraulic, thermal prosesses, which are relevant for energy piles. The concept can be utilized for 1D, 2D and 3D models in cartesian or axisymmetric coordinates, for steady-state as well as for transient problems. Moreover convective processes resulting from groundwater or seepage water flow can be taken into account in addition.

Reference

Bodas Freitas T.M., Cruz Silva F., Bourne-Webb P.J., The response of energy foundations under thermo-mechanical loading, 18th Intern. Conf. on Soil Mech. and Geotech. Engineering, Paris, Proceedings, 3347-3350, 2013
Laloui L., di Donna A., Energy Geostructures, Wiley & Sons, 2013

Figures used in the abstract

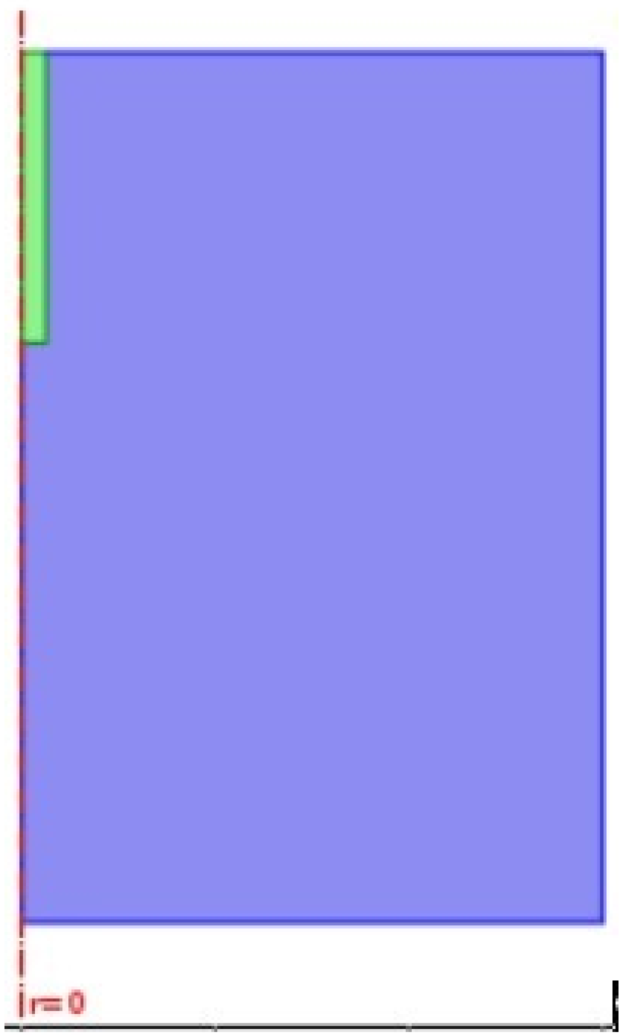

Figure 1: Energy pile model region in axi-symmetric coordinates

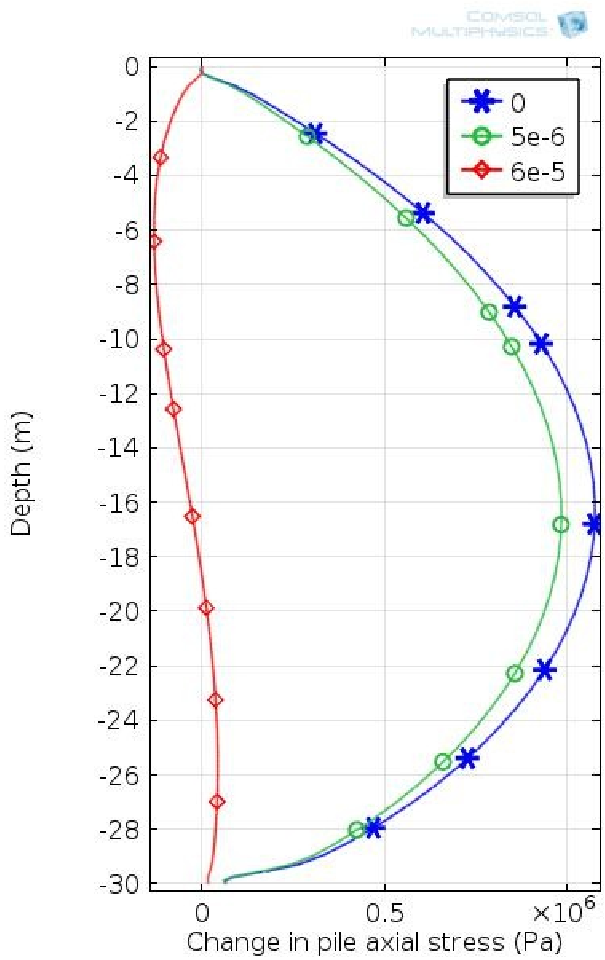

Figure 2: Change in pile axial stress in dependence of ground thermal expansion factor

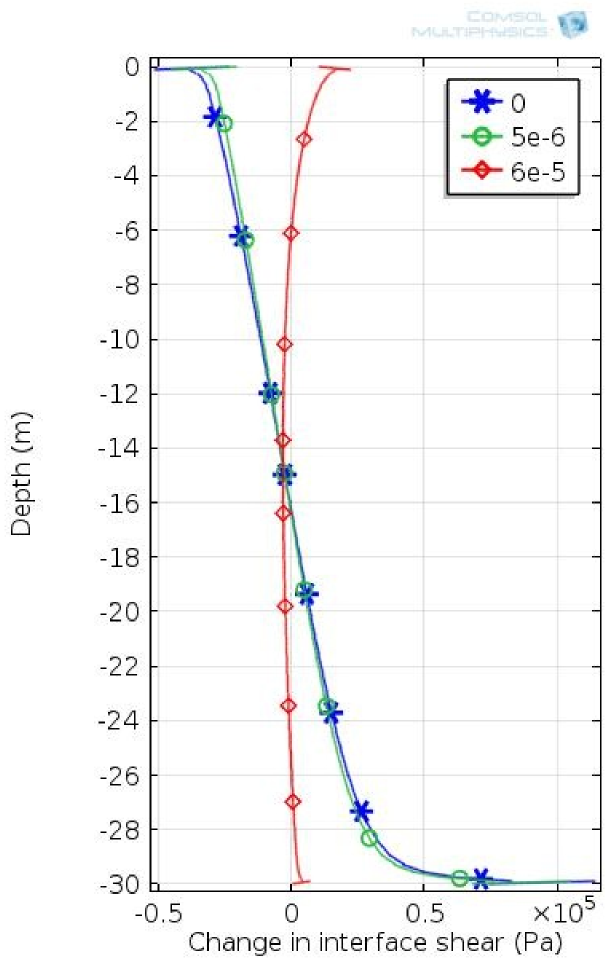

Figure 3: Change of interface shear in dependence of ground thermal expansion factor

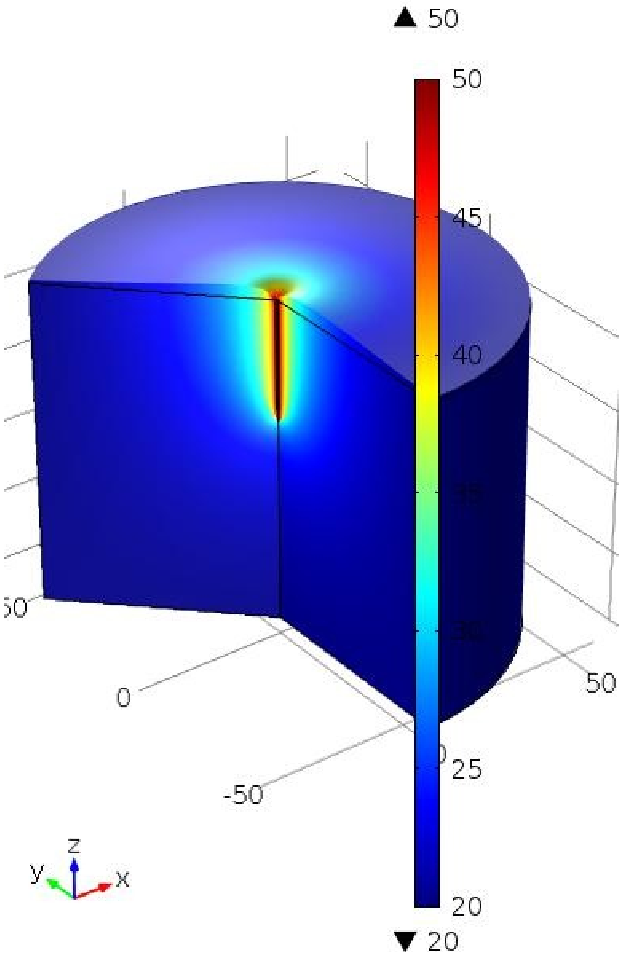

Figure 4: Temperature [°C] distribution around the pile