# Analysis of Multiphysics Problems Related to Energy Piles

J.A. Infante Sedano, E. Evgin, and Z. Fu
Department of Civil Engineering, University of Ottawa, Canada

**Introduction**: Deep foundations which transfer the mechanical loads from buildings to the ground and also serve as heat exchangers are called energy piles as shown in Fig.1.

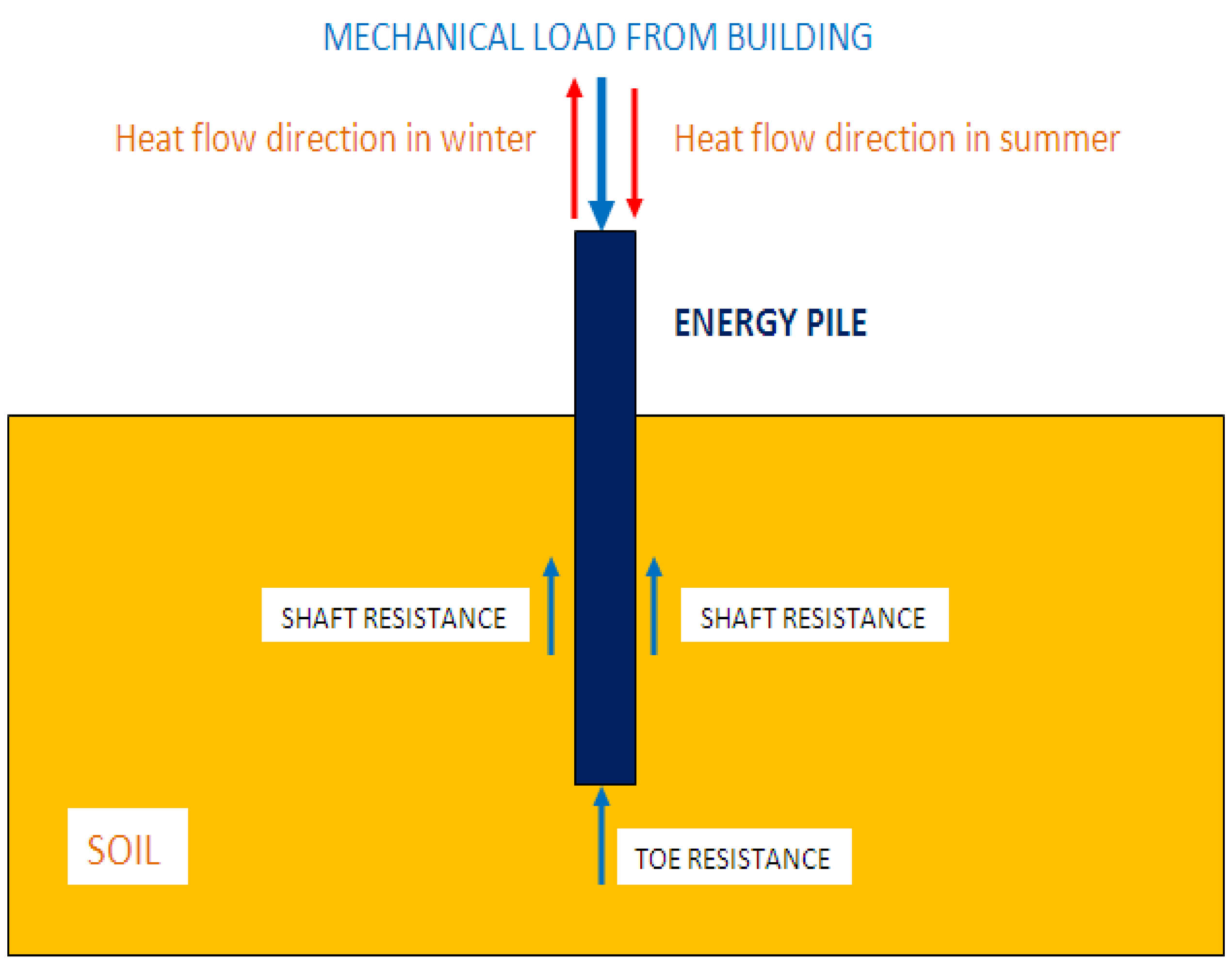


**Figure1**. Dual function of an energy pile.

Temperature changes in the ground influences its moisture content as shown in Fig.2. This paper examines the effect of soil moisture content on the shaft resistance of a pile. COMSOL is used to model the load-deformation curve of a 10m long pile embedded in a soil with variable moisture contents based on temperature fluctuations.

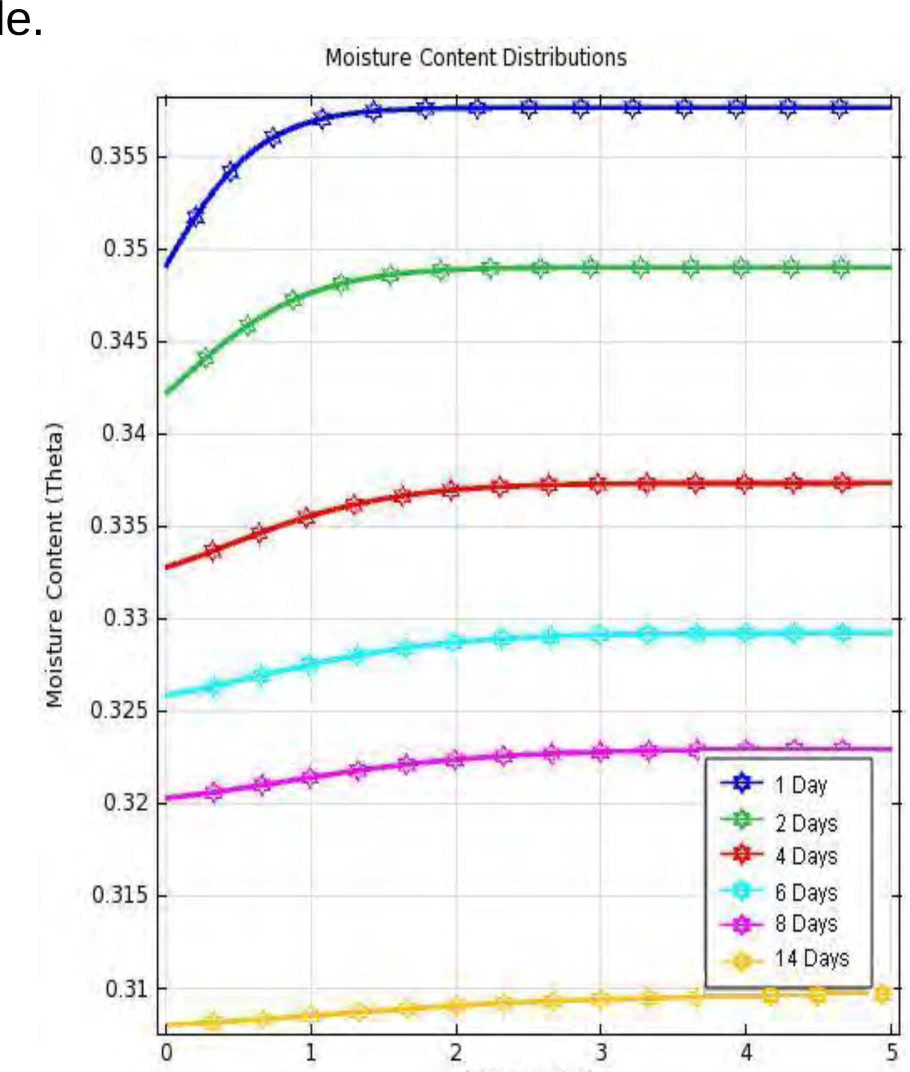


**Figure2**. Moisture content distribution in the soil mass as a function of time.

## Laboratory Tests: Effect of Soil Moisture Content on Soil–Pile Interface Behaviour

Table 1. Effect of moisture content on interface friction angle and adhesion.

| Moisture content | Interface Friction angle($\delta$)( °) | Adhesion ($f_2$) (kPa) |
|---|---|---|
| w=10% | 25.1 | 10.6 |
| w=15% | 26.5 | 11.5 |
| w=17.5% | 28.3 | 13.9 |
| w=21.5% | 27.2 | 12.3 |

## Shaft Resistance of a Pile

**Conventional Method of Calculation:** The shaft resistance of a pile is determined using Eq.1. (Das, 2002)

$$Q_S = \Sigma\, r_s\, p\, \Delta L \qquad [1]$$

**Finite Element Analysis using COMSOL:** A single pile shown in Figure 3 is divided into 10 sections. The interaction between a pile section and the soil is treated as a contact mechanics problem as shown in Fig.4. The shaft resistance of the entire pile is the sum of the contributions of all pile sections (Fig. 6).

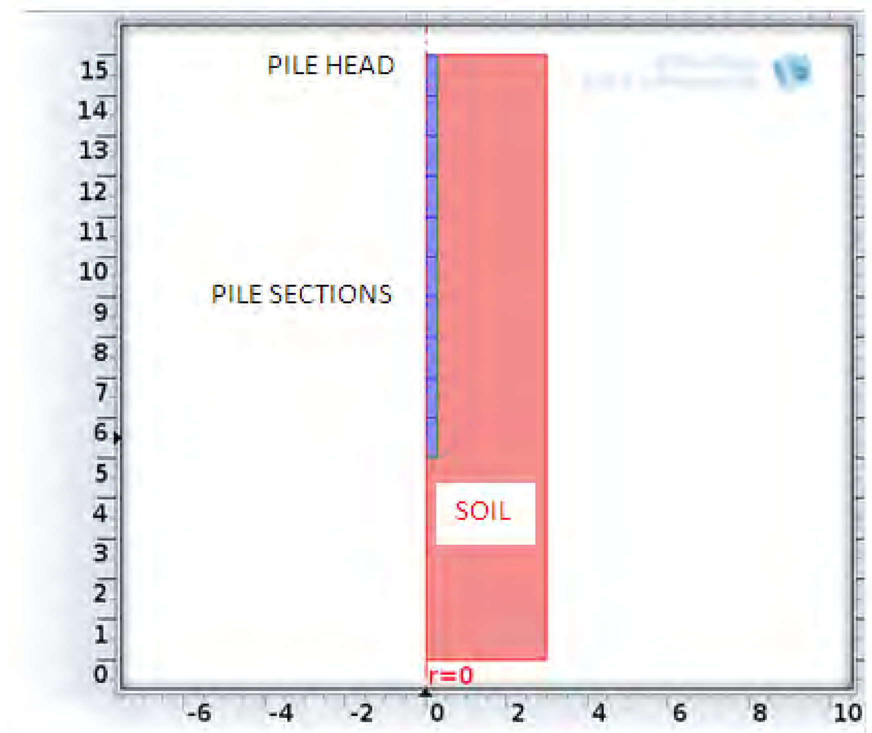


**Figure3**. Pile sections.

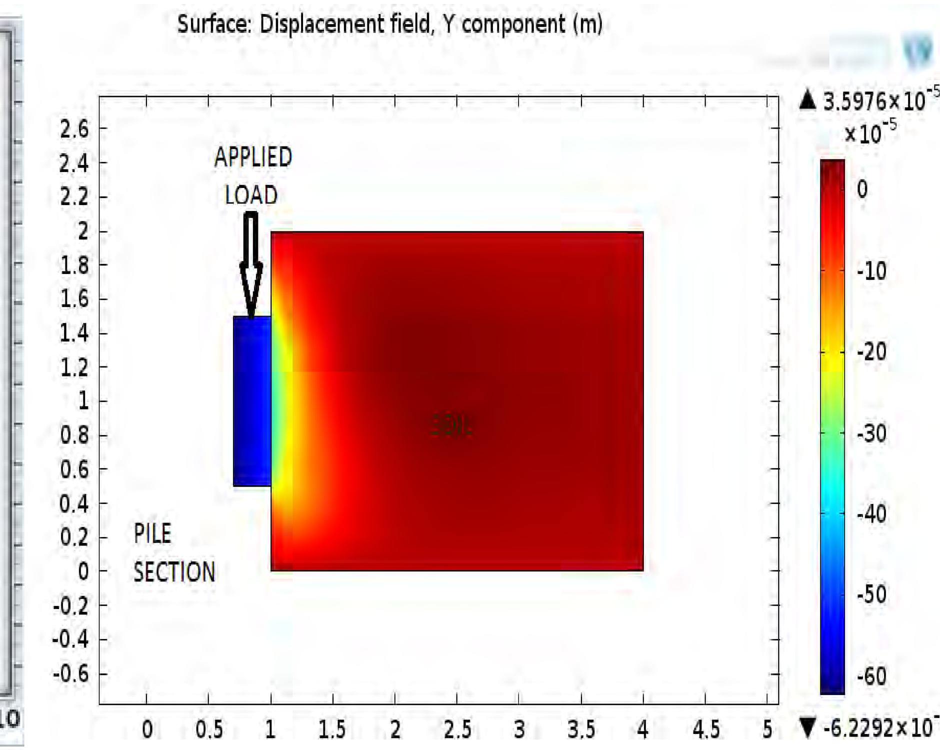


**Figure4**. Shaft resistance versus vertical displacement of one of the pile sections.

The elastic modulus of soil is assumed to be a function of stress level and calculated by Eq.2 (Kondner,1963)

$$E = Kpa\left(\frac{\sigma_3}{Pa}\right)^n \qquad [2]$$

## Results

The applied load versus the corresponding movement of each pile section is shown in Fig. 5, where the uppermost pile section is labeled as #1, and the deepest section is #10.

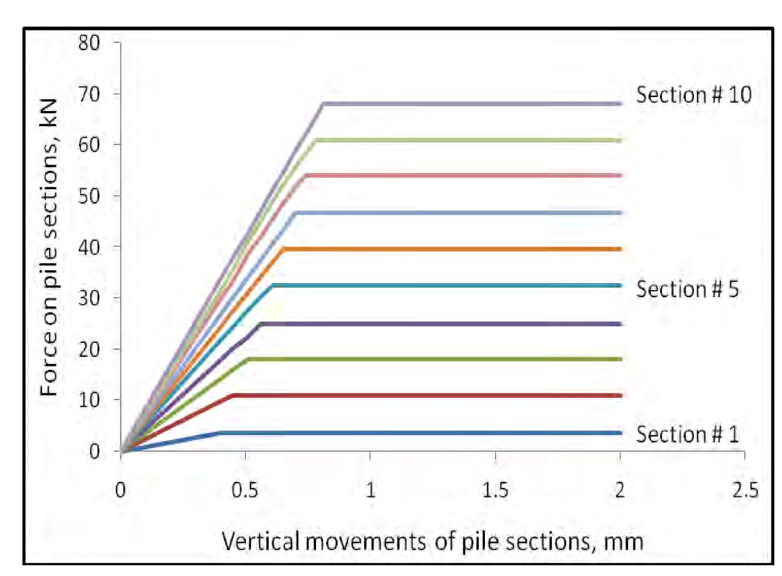


**Figure5**. Applied load versus vertical movement of each pile section. (COMSOL results)

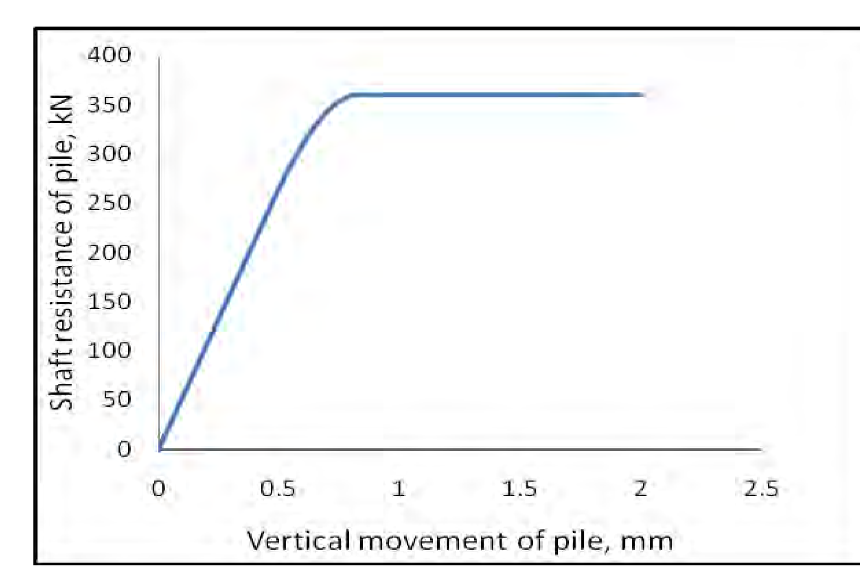


**Figure6**. Shaft resistance versus vertical movement of the pile (w=10%).

The shaft resistance calculated by COMSOL compares well with the results of textbook calculations as shown in Fig 7.

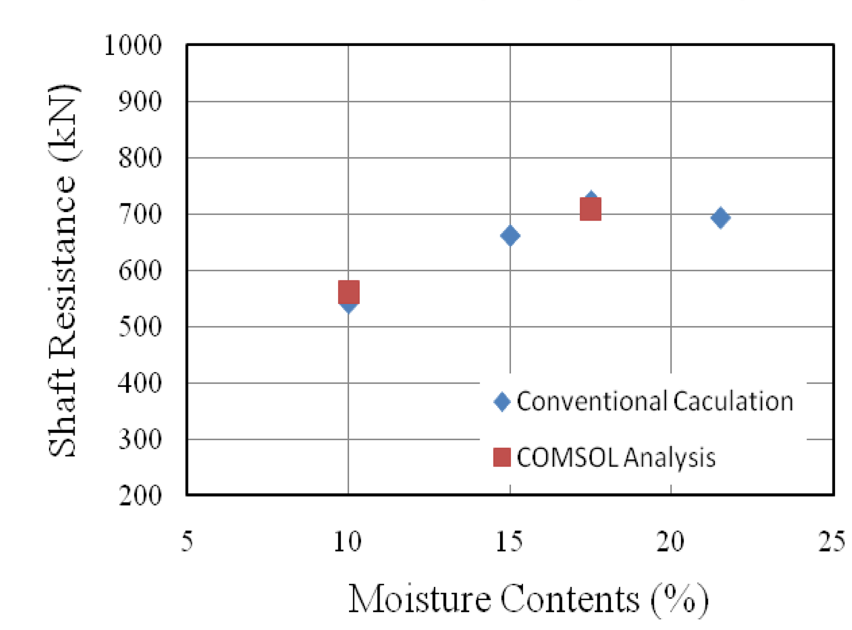


**Figure7**. The pile shaft resistance versus moisture contents.

## Conclusions

1. The shaft resistance of an energy pile can be calculated using the Contact Modeling option of COMSOL Multiphysics code.
2. The vertical movements of a pile head as a function of load carried by the pile shaft can be determined for various soil moisture contents.
3. Soil moisture content can be affected by variations in temperature. The working model described in this paper can readily be used in the analysis of heat transfer, fluid flow and mechanical aspects of energy piles.

## References

1. Brandl, H. Energy piles and diaphragm walls for heat transfer from and into the ground. *Deep Foundations on Bored and Auger Piles,* Van Impe & Haegeman, Eds: 37-60. 1998.
2. Kondner, R.L. Hyperbolic Stress-Strain Response: Cohesive Soils. J.of Soil Mechanics and Foundation Division, ASCE, Vol. 89, No. SM1, pp.115-143, 1963.