Numerical Analysis of Shaft Resistance and Toe Resistance of a Pile in Unsaturated Soil

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Abstract

Piles transfer structural loads to the ground (1) at the surface of their shafts and (2) at their toes (Fig.1). In the numerical analysis of these two components of load transfer from a pile to the soil mass, both the deformation characteristics and the strength properties of the soil have to be taken into consideration. In unsaturated soils, matric suction changes the stress-strain-strength behaviour of the soil. Similarly, the adhesion and the friction angle at the interface between the soil and the pile shaft are affected by changes in matric suction.

In this paper, the effect of matric suction on the shaft resistance of a pile is examined. The pile in consideration is described by Georgiadis et al. (2003). This pile was also used by Georgiadis (2003) to demonstrate the usefulness of a newly developed constitutive relation for unsaturated soils. The behaviour of the same pile was analyzed by Taylan et al. 2012 using SIGMA/W and the Imperial College Finite Element Program (ICFEP). In the present study, COMSOL Multiphysics® is used. Soil-pile interaction is analyzed as a contact mechanics problem rather than using conventional interface elements. The required deformation and strength parameters for the soil are elastic modulus, Poisson's ratio, cohesion, and friction angle. Above the groundwater table (GWT), the effects of matric suction on soil parameters were taken into consideration as described in the paper. The pile is embedded in a soil with linearly varying matric suction between the ground surface and the GWT (Fig. 2). The depth (D) to the GWT is also considered as a variable. A detailed description of the methodology to calculate the toe resistance and shaft resistance with respect to the related pile head movement is provided.

The properties of the contact zone between the soil and the pile are expressed as a function of matric suction in the soil. A solution of this multiphysics problem requires the simultaneous use of the Structural Mechanics and Geomechanics Modules.

The results of COMSOL are compared with the results of conventional methods Das (2002) and the results of Taylan et al. (2012).

Reference

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Georgiadis, K., Potts, D.M., and Zdravkovic, L. 2003. The influence of partial soil saturation on pile behaviour. Géotechnique, Vol. 53, No. 1, pp. 11-25.

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Figures used in the abstract

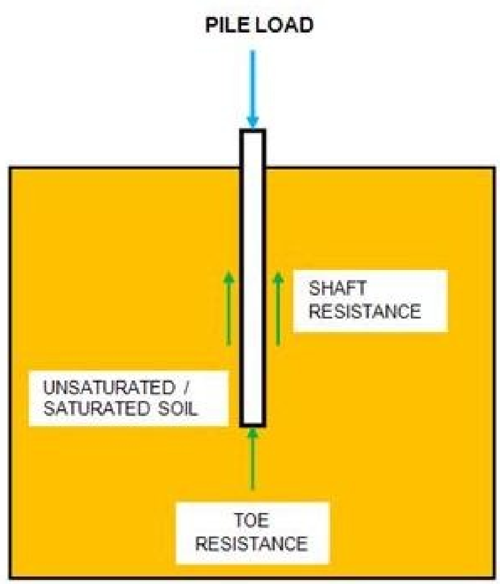

Figure 1: Figure 1. Load transfer mechanism from a pile to soil mass

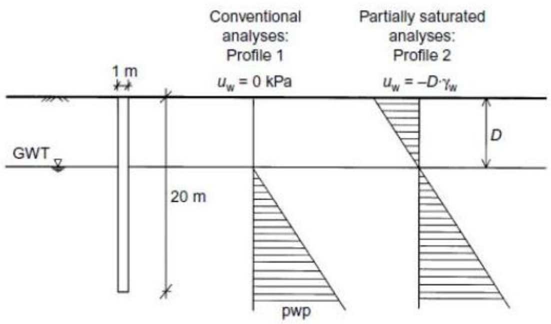

Figure 2: Figure 2. Pile dimensions and porewater distribution (Georgiadis et al. 2003)