

## NUMERICAL ANALYSIS FOR ELECTRO-OSMOTIC CONSOLIDATION IN TWO-DIMENSIONAL ELECTRIC FIELD

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### ABSTRACT

A numerical model is developed for the design and analysis of electro-osmotic consolidation in soft soil. Finite difference method is used for estimating ground settlement increase in soil shear strength induced by electro-osmosis. A well documented full-scale field test is analyzed using the numerical model for verification. Sensitivity analysis is conducted to address the uncertainty of the model. The results from the numerical analysis are consistent with the measurement of the ground settlement and soil undrained shear strength after the field test. The results indicate that the soil improvement induced by electroosmosis is sensitive to the electroosmotic conductivity and the voltage distribution in the soil.

**KEY WORDS:** Soil stabilization; soft ground improvement; electro-osmotic consolidation; numerical analysis.

### INTRODUCTION

Soil improvement by electro-osmosis involves applying a direct current (dc) voltage across electrodes embedded in the soil. The dc current drives soil pore water from the anode toward the cathode. If water is permitted to drain at the cathode and prohibited to enter the anode, a non-uniform negative excess pore water pressure will be induced in soil by electroosmosis, which leads to consolidation (Casagrande 1949; Esrig 1968; Wan and Mitchell 1976) and consequently reduction of soil water content and increase in soil shear strength. Furthermore electro-osmosis can accelerate dissipation of the excess pore water pressure induced by the surcharge pressure. Ersig (1968) proposed analytical solutions to calculate the excess pore water pressure in a one-dimensional uniform electric field in which the electric field intensity is constant. Wan and Mitchell (1976) derived analytical solutions to calculate the excess pore water pressure for the electro-osmotic treatment in a uniform electric field with a surcharge pressure. Shang (1998) developed an analytical solution for the electro-osmotic consolidation in a uniform electric field in anisotropic soil with a surcharge pressure. The author estimated the undrained shear strength

based on estimated preconsolidation pressure due to the electro-osmosis and surcharge pressure.

The distribution and intensity of the electric field intensity in an electro-osmotic treatment are determined by the layout of electrode rows installed in soil and the dc voltage applied across the electrode rows. The analytical solutions for a one-dimensional uniform electric field may not be applicable for most applications in the vicinity of electrodes. Lewis and Humpheson (1973) formulated a finite element model to analyze the electro-osmotic flow in two-dimensional electric fields. Governing equations of electric current and electro-osmotic flow in soil were established. Su and Wang (2003) established analytical solutions for estimating the excess soil pore-water pressure in a two-dimensional electric field. The solutions were developed based on governing equations used by Lewis and Humpheson (1973). The electric field is expressed as an arbitrary spatial function. The explicit solution of the electric field distribution as a function of the electrode layout is not considered in the solution. Furthermore, the authors assumed that the electrode is dimensionless, which is approximately valid only for large electrode-to-electrode spacing. Previous studies assumed that the soil electrical and mechanical properties remain constant during electro-osmotic consolidation. However, the soil electrical conductivity in the vicinity of electrodes decreases significantly and rapidly during the electro-osmotic treatment, which results in significant voltage drop in the vicinity of soil-electrode interface (Bjerrum et al. 1967; Wade 1976; Lo et al. 1991). Effects of the decrease in the soil conductivity on the electro-osmotic consolidation have not been studied systematically in the literature.

This study develops a numerical model to analyze the electro-osmotic consolidation of soil subjected to two-dimensional electric fields. Effects of the electrode dimensions and voltage drop in the vicinity of the soil-electrode interface are incorporated in the electric field distribution and intensity analysis. Since the electro-osmosis generates a non-uniform pore water pressure in soil, a time-dependent spatial function of soil compressibility is used for the analysis of electro-osmotic consolidation settlement. The finite difference model is verified using the results of a well-documented field test on a soft clay.