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Slope stability improvement using low intensity field electrosmosis

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The electrosmosis technique has been introduced in the past for slope stabilization. However, its application to real cases has been scarce due to several drawbacks mostly related to the high intensity electric field needed (1.0 V/cm or higher): the rapid degradation of the electrodes, the high system management cost, the heating and cracking of the soil and the reduction of its colloidal fraction. Thanks to the introduction of new materials, the technique is currently applied to decrease the consolidation time of saturated clay soils (forcing the elimination of water), consequently improving its mechanical strength.

In clay soils, the volume variation is influenced by the presence of smectites. The clay compressibility decreases with the increasing of electrolytes concentration. Soil containing smectites that have interacted with calcium showed a reduction or the absence of swelling during hydration with distilled water and a positive increase of their shear strength.

The different values of pH between the anode (acid) and the cathode (basic), induced by the electrosmosis create the conditions for the precipitation of $CaCO_3$ near the cathode. The injection of solutions containing calcium in soils and their diffusion induced by the electrosmosis, lead to calcium precipitation and consequential increase of the shear strength.

The material technological advances and the laboratory experiences described in this paper, demonstrate that the use low electric field (0.1 V/cm or lower) intensity electrosmosis (LEFE in acronym) can be effective for soil dewatering and shear strength increase while reducing its adverse effect. The LEFE can be used to:

- reduce the potential for swelling of active clay minerals through the introduction of ions and the precipitation of hardening substances;
- induce the "dewatering" in cohesive soils.

Several Lab activities were carried out, using custom made electrosmosis equipment. These activities can be divided in two phases:

- Phase 1: Carbonates were mixed to a natural soil obtaining three groups of soil samples at different carbonates level; the geotechnical characterization of each group was carried out;
- Phase 2: LEFE was applied to induce the precipitation of $CaCO_3$, the reduction of the swelling potential of clay minerals and the increment of the soil shear strength.

The outcomes of Phase 1 indicated that:

1. the values of specific gravity of the grains, plasticity index (PI) and Value of Blue (VB) decrease with the increase carbonate content;
2. the shear strength increases with the carbonates content.

From the second laboratory phase, we observed:

1. an almost constant pH values within the sample;
2. an increment of the carbonate content after LEFE treatment regardless of its duration; this increment is particularly significant after 60 days of treatment;

3. a reduction of the swelling potential of soil;
4. that the water content at the end of each treatment, regardless of its duration and intensity of the electric field, shows similar values;
5. that the values of the soil shear strength (after 60 days of LEFE treatment) are always greater than those of the natural soil (average +7%).

During the LEFE treatment, the pore fluid used is water taken from the local groundwater, with pH = 7.3 and hardness of 34.6 °F. The $CaCO_3$ content in treated samples increases with the duration of treatment.

The application of LEFE appears to be effective in increasing the carbonate content and improve mechanical strenght of the soil; further development of the research will apply the LEFE to an ideal slope model and to a real case.