Waste Containment by Soil Stabilization Using Electro-Kinetic Grouting Method

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Abstract: Solidification/stabilization of soil reduces mobility of hazardous substances and contains the pollutants in their environment. Unlike other remedial technologies, soil stabilization seeks to trap or immobilize contaminants within their host soil medium, instead of removing them through chemical or physical treatment. A relatively new technique, electro-kinetic grouting, may be applied toward solidification of soil, reducing its permeability and thereby containing the pollutant within a specified area. The underlying theory behind this study is based on the following presumption: when a d.c. current is applied across a sandy soil mass, sodium silicate (most common chemical grout) in the cathode compartment and reactants like calcium chloride in the anode compartment, are expected to migrate. The anionic silicate will migrate toward the anode due to electro-migration (movement of charged particles toward the opposite charged electrodes) and cationic metal ions will migrate toward the cathode. When these charged ions meet within the soil, the pH of the sodium silicate will be reduced and it will form a gel within the soil and grout/solidify the soil. In silty soil where electro-osmosis (pore water flow from anode to cathode) occurs due to application of d.c. electric field, it is expected that water-soluble sodium silicate grout will be carried away by electro-osmotic flow from anode toward cathode. When the pH of this grout is reduced by the H^+, generated and migrated (electro-migration) from the anode, the sodium silicate grout will form a gel and stabilize the soil.

These basic concepts were used in a study of stabilization of sandy and silty type of soils. Results obtained from the laboratory 1-D column tests indicate possible solidification, shown as an increase of strength.

Results. To evaluate the feasibility of grouting (stabilization), the 1-D column experiments were performed by electro-kinetic injection of sodium silicate (pH 11.3) and reactants to the two types of sand: (1) sand (100%) and (2) sand-silt mix (50/50). The electro-kinetic cell (Figure 1) used for the experiments was made from Plexiglas tubing (length of 32 cm and diameter of 5.1 cm). The actual length of the soil specimen inside the Plexiglas tube ranged from 23 to 24 cm and it was placed in the middle of the sample tube. The soil specimens were prepared by saturating with either 0.01 N, or 0.1 N NaCl solutions. Graphite electrodes were placed at the ends of these tubes. Two porous plastic discs were used to separate the soil from the electrodes at each end of the soil column. This space constituted a small fluid compartment at the cathode and anode. Depending on the tests, these fluid compartments were filled with water, 50% sodium silicate or a reagent. Fluid levels at cathode and anode compartments were maintained at almost the same level to avoid any hydraulic gradient. The electrodes were connected to a d.c. electric power supply.

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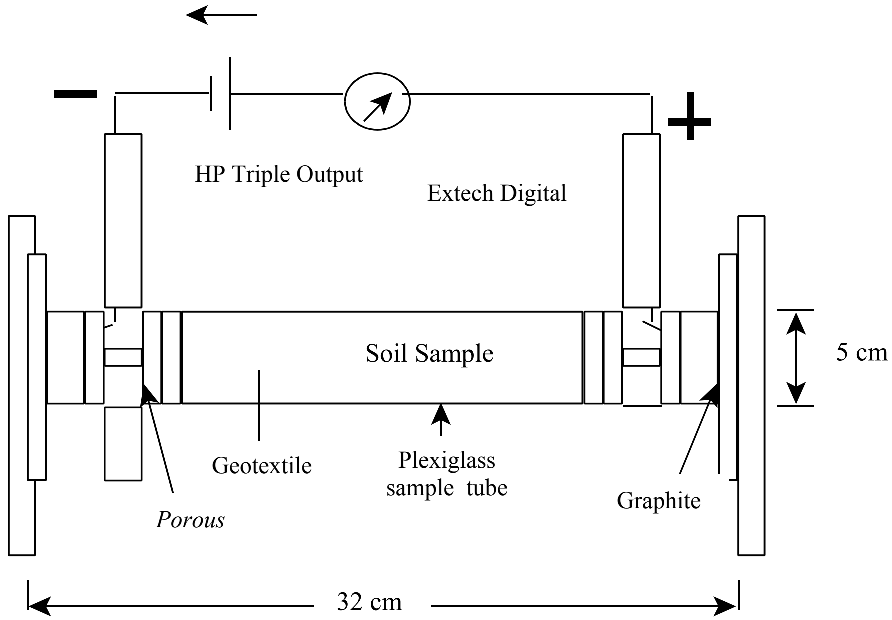
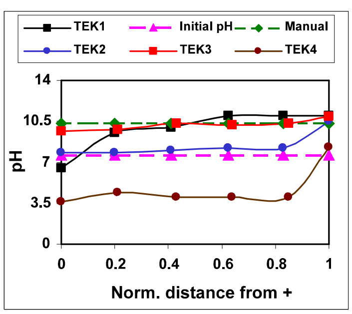


Figure. 1. The electro kinetic cell.

Test with sand (100%): Tests (TEK1, TEK2) were performed on 100% sand over duration of 5 days with pore water of 0.01N NaCl. The only difference between TEK1 and TEK2 was that in TEK1 voltage gradient was 1.53 V/cm whereas in TEK2 it was 0 V/cm. The purpose of TEK2 was to compare and evaluate the effects of electro-migration of silicate ions in TEK1 with no migration in TEK2. In TEK1, post treatment pH of soil increased from 7.6 to 11.0 (Figure 2). Soil-conductivity of treated specimen ranged 0.004 to 0.3 s/m where initial conductivity of the soil specimen was 0.028 s/m (Figure 3).



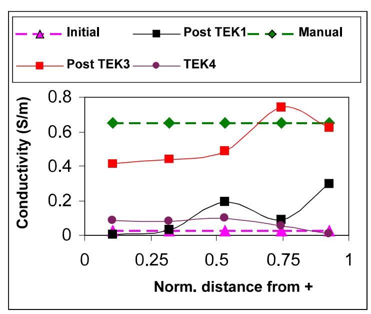
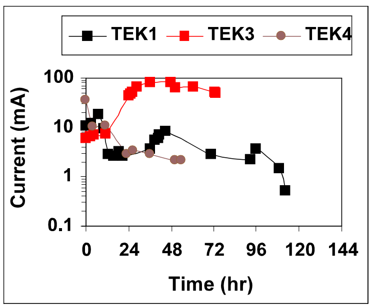


Figure 2 and 3. Changes in pH and conductivity measurements.

This change could be explained by the possible intrusion of silicate into the soil, perhaps due to electro-migration under the influence of the electric field. Current (Figure 4), in TEK1 had an increasing trend at the beginning of the experiment, but it decreased with time. This may be due to precipitation at the electrodes, air bubble formations due to electrolysis at the electrode chambers, etc. Some noticeable stabilization of soil was observed in the cathode region. Electro-osmotic fluid flow did not occur in these tests. In TEK2, pH, soil conductivity remained almost the same as the initial condition of soil indicating no silicate intrusion. Also, the above parameters (pH, conductivity) of TEK1 were almost the same as manually mixed sand.

Test with sand-silt mix (50/50): Tests (TEK3, TEK4) were performed on 50% sand and silt mix with pore fluid 0.01N NaCl. The only difference between TEK3 and TEK4 was that the TEK3 used silicate in the anode compartment and water in the cathode compartment, whereas TEK4 had only water in both compartments. The purpose of TEK4 was to compare and evaluate the effects of intrusion of silicate ions by electro-osmosis in TEK3 with no migration of silicate in TEK4 due to its absence. In TEK3, post treatment pH increased to a range of 9.7 to 10.9 from the initial pH of 7.6 (Figure 2). Soil-conductivity increased to a range of 0.4 to 0.7 s/m, which is almost the same as the soil conductivity of manually mixed soil of the same chemicals 0.69 s/m (Figure 3) at the same dose. Current increased with time up to 81.12 mA from the initial value of 6 mA. There was a noticeable stabilization of soil throughout the specimen and it gained an unconfined strength (unconfined compressive strength) of 600 KPa near the anode region with 285 Kpa at the cathode. All these four sets of data are marks of silicate intrusion into the sand-silt mix due to electro-osmosis under the influence of the electric field. This silicate injection rate was of the order of 10^{-4} to 10^{-5} cm/s/v/cm (Figure 5).



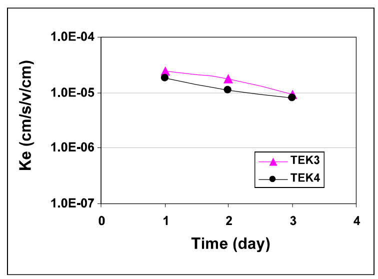


Figure 4 and 5. Changes in current flow and electro-osmotic permeability

Conclusions. This study confirmed possible migration of silicate ions in both sand and silty-sand, which leads to stabilization of soil. In the silty soil, grout injection rate per voltage gradient (V/cm) was almost an order of magnitude higher than the injection rate due to unit hydraulic gradient. Grout injection rate in the silty soil can be increased by increasing the applied voltage gradient.

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