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Stabilization of Sandy Clay Using Electrochemical Injection

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ABSTRACT

Soil is basic material of construction propped the foundation that supports structure. But sometimes soil needs to be changed to make area more suitable for building. The aim of research is to explore the preventive method of soil improvement. Laboratory experiments have been carried out in pilot scale and based on electro kinetics phenomena In the model test was used sandy clay (70% of caolinite +30% of sand) and Na2CO3 2N + $CaCl_2$ 10%. As injected chemical solution. The successful of this method can be seen by comparing strength of soil before and after test.
Keywords: electro chemical, sandy clay, shear strength.

INTRODUCTION

Whether the soil is used as foundation to support buildings, road or is used to built some structure such as earth dam, it is desirable that the material possess certain properties. The soil should be have adequate strength, relatively incompressible to evoid excessive settlement, be stable against voleme change as water content and possess proper premeability. Even the natural soil at a planed construction site are too weak (soft soil), method of site improvement may be possible and practical. A lot of method to improve soil behavior such as remove the material and replace it with the compacted earth fill (mechanical stabilization), reinforcement and chemical additive.

Lime and calcium chloride have been used as additive to improve mechanical behavior of clay mineral. The material more friable than original, decrease plasticity, prevent volume change in expansive clay. Stabilizaton material will be mixed outer of the site, spreaded it then curing for a few days. Electrochimical injection is one of chimical additive stabilization that improve characteristic clay mineral without need change the site. Moreover the method can be done for soil under the structure that failure was generated.

Relationship between electrical current and water with gradient in fine media, it is reconized as electrokinetic phenomena. Coupling between electrical and hydraulic flows and gradient can be responsible electro kinetic phenomena in materials such as fine-grained soil, where there are charged particles balanced by mobile counter charges. There are four recognized electro-kinetic phenomena that occur in soil-water mixtures. These are: [1][2]

- Electro-osmosis, movement of water through a solid matrix under an electric field
- Electrophoresis, movement of suspended particles through water under an electric field
- Streaming potential, small electric field caused by the movement of water through a soil matrix
- Sedimentation or migration potential, small electric field caused by movement (sedimentation) of solid particles through water, or movement of cautions and anions under an electric field

Of these phenomena, electro osmosis and electrophoresis are the most relevant to the commercial application in Geo-engineering and Geo-environmental. Electro osmosis generally occurs in soils, and electrophoresis tends to occur in slurries and colloids [3][4].

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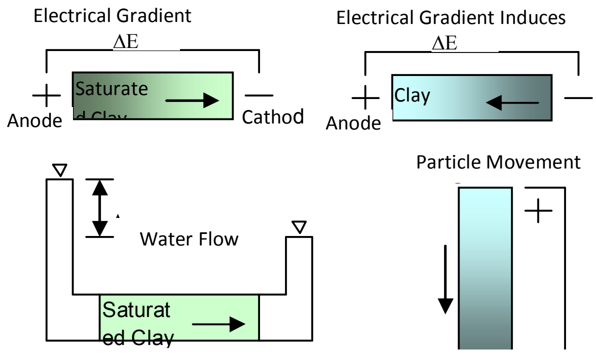


Figure 1: Electro-kinetic phenomena, electro-osmosis, electrophoresis, streaming potential and migration or sedimentation potential (clock wise), after Mitchell (1993) [5]

The Helmholtz-Smoluchowski theory is the generally favoured theory of electro-osmosis and the condenser analogy it adopts assumes that the soil capillaries have charges of one sign on or near the surface of the wall (negative) and counter charges (positive) concentrated in a double layer protruding a small distance from the wall, the remaining void is assumed to be filled with free pore fluid, as shown below

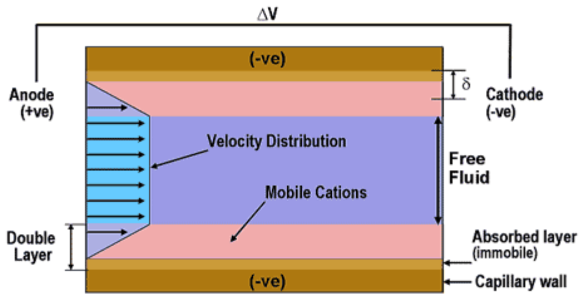


Figure 2 Helmholtz-Smoluchowski Model for electro-osmotic flow (After Mitchell, 1993) [5].

The Helmholtz-Smoluchowski theory states that upon the application of an electrical potential difference across the system the mobile shell of counter-ions drags water through the capillary by plug flow, resulting in a high velocity gradient between the two plates of the 'condenser'. The rate of water flow is controlled by the balance between the electrical force causing water movement in one direction and friction between the liquid and the wall in the other. The overall flow (qA) generated by the application of a potential difference (D) may be expressed as [5]:

$$q_e = k_e i_e A \qquad (1)$$

Where k_e is the electro-osmotic permeability of the soil; i_e is the electrical potential gradient; and A is the cross-sectional area of the soil sample across which the potential difference is applied. As such this is analogous to Darcy's Law of hydraulic flow. Where q is the flow rate; k_h is the hydraulic permeability; i_h is the hydraulic gradient and A is the cross sectional area of the soil. [5]

$$q = k_h i_h A \qquad (2)$$

The overriding benefit of electro-osmosis is that k_e is independent of pore size and has a relatively constant value in soils. This is k_e contrast to hydraulic permeability (k_h) which decreases markedly with pore size as shown below.

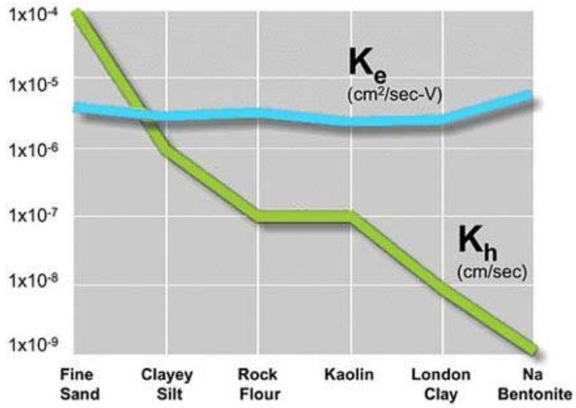


Figure 3 Electro-osmotic performances over a range of soils

This means that as soils become finer and more impermeable, the relative benefit of electro-osmoses flow increases. The net result is that electro-osmosesis can cause significant flow of water in materials that under normal circumstances are effectively impermeable.

Soil stabilization by using chemical additive, a cemented material, or some chemical material is added to a natural soil to improve one or more of soil properties. For example, sodium chloride (salt) and calsium cloride are additives for water holding properties. Spread on soil surface prevent dust is particularly useful for stabilizing silty soil in dry clime.They have effect also of preventing frost heave in soil by lowering the freezing point of water. The treatment will be temporary if leaching by groundwater is occured.

Hidrated lime Ca(OH)2 is used to stabilize clay soil and sandy clay. Sametime lime is mixed by portland cement, bitumen and fly ash. Lime and calsium cloride (CaCl) is also used to decrease plasticity by exchanging of cation in the adsorved water layers. When mixed with exspansive clay will prevent volume change. The result of material is more friable than original clay.Various combination commercial and natural chemicals have been success as cementing agents for soil such as silicate chemicals, polymers and chrom lignin. The sodium silicate mixed with calsium cloride reacts quickly to form calcium silicate to perform hard and improvious material. The chemicals are basicly water soluble and produce reaction to bounding soil particle without change characteristic of particle. Clay is fine grained soil which easy to influances of the water and has large inpact on strength. The slurry clay can be dried by passing liquid, plastic, semisolid state and finally solid state. Shear strength ussualy will be change oppesite with water content. Controlling water in fine-grained soils is therefore of paramount importance but presents recurrent problems owing to the very low hydraulic permeability of the materials. The propose of injection may be any one or more such as to decrease permeability, increase shear strength and decrease compresibility of soil.

MATERIALS AND METHODS

Soil material are consist of 70% clay and 30% volcanic sand. Properties of sandy clay are tested by Indonesian Standard (Tabel 1)

Tabel 1Testing method of soil properties

No	*Types of Testing*	*SNI-Code*
1	Soil water content	03-1965-1990
2	Specific gravity of soil	03-1964-1990
3	Liquid limits	03-1967-1990
4	Plastic limits	03-1966-1990
5	Compaction	03-2832-1992
6	Permeability	03-2435-1991

The apparatus is designed based on the next application in the field and available literature [6]. The apparatus box (50 x 50 x 20 cm) is made of Plexiglas which is chemically inert and allows visual inspection. To change product DC electricity from AC it is utilized adaptor, and for stabilize the electric current flow is used regulator. Chemical solution is filled in opened Plexiglas cylinder which is performed small plastic pipe for flowing fluid. A schematic diagram of the electrochemical injection apparatus is presented in Figure.4.

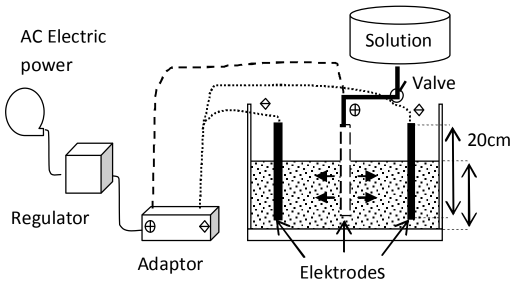
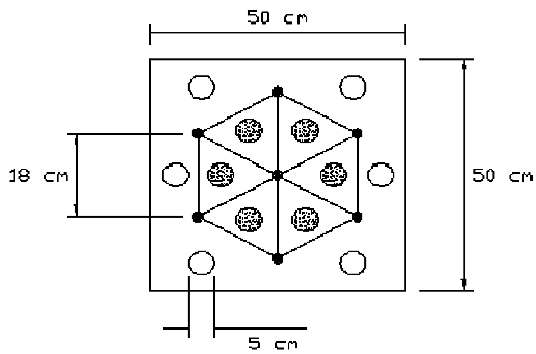


Figure 4 Model test apparatus of electrochemical injection

Kaolin powder and fine – medium volcanic sand are mixed by hand in dry condition. The mixed soil sample is added by dionized water and is mixed again. The wet soil sample is kept in two days, therefore filled in the Plexiglas box at three layers. To avoid the air bubbles and to reach high density the samples are compacted by wooden roll. The thickness of every layer is 5 cm. Therefore six anodes which is made of copper pipe and bored in all side are stacked in soil material and performed six edges. The cathode is put on the centre. The distance between cathodes with anode, and inter anode is 18 cm (Figure 5).

The chemical solutions were flowed gravitationally from plastic cylinder to anodes through small plastic pipe. Solution of $CaCl_2$ 10% and Na_2CO_3 were used in this model test, The electric potensial betwen electrode is setted up 1 V/cm. The electrochemical injection experiments are carried out in 10 days (Figure 5).



○ Anode pipe
● Cathode pipe
◯ Sampling point before injection
◯ Sampling point after injection

Figure 5 Position of electrode and soil sampling for shear strength test

Chemical solutions were flowed gravitationally from plastic cylinder to anodes through small plastic pipe.During experiment the volume of solution which flow to anode, and drained from cathode are recorded every two hours. Electric gradient and current between cathode and anode recorded every one hour. The electrochemical injection were carried out in 7 days, theren flowing solution to anode was stopped. However, electric current is still set up in 3 days, in order to dewatering process run well and water content of soil, before and after treatment are most equal.

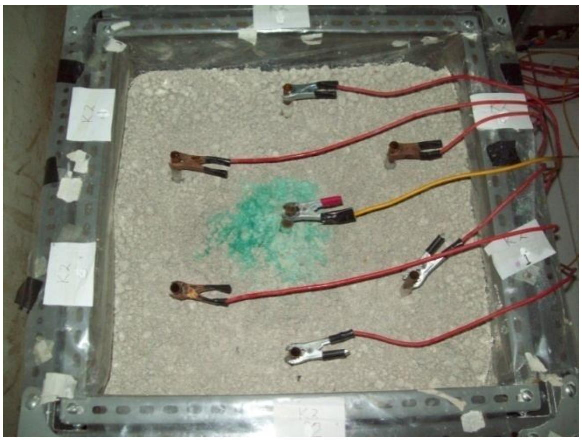


Figure 6 performing of electrochemical injection model test

Six soil samples are obtained from experiment apparatus before the electrochemical injection, and 6 samples after treatment. Several tests like water content, unconfined compression test and unconsolidated undrained (UU) triaxial test will be done to know the mechanical properties, and X-Ray Diffraction test to identify mineral composition. The exchange of mechanical properties and mineralogy are distinguished by comparing of the test result before and after treatment.

Table 2 Mechanical properties test of fine grained soil

g	*Type of Test*	*SNI-Code*
1	Unconfined compression	03-36381994
2	Unconsolidated Undrained Triaxial	03-48131998

RESULTS AND DISCUSSION

The physical properties of sandy clay

The phisical properties of sandy clay before injection can be shown in Table 3.

Table 3The phisical properties of sandy clay before threatment

Atterberg Limit			**Compaction**		**Permeability**
LL	PL	PI	w_{opt}	γ_{max} (gr/cm^3)	kh cm/dt
35,29	15,54	19,76	26%	1,419	6,089x10^{-8}

Soil samples are classified to inorganic clay with medium plasticity and the symbol CL.

Electricity Gradient

During the experiment the electric potencial between two electrodes for all types solution are up and down, although the difference of maximum and minimum value is small (18 volt $\pm$2volt)

Stream Solution and Drained Water

Stream solution Na_2CO_3 2N + $CaCl_2$ 10%. was flowed from anode to cathode. Amount of solution can be injected to soil is shown in Figure 5.

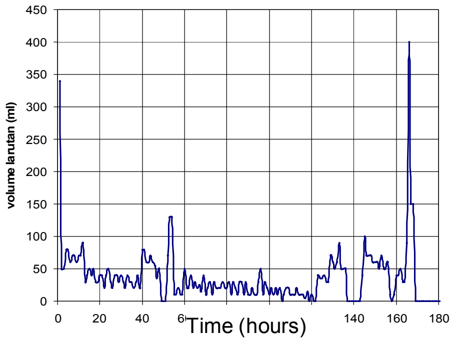


Figure.7 Streamed solution through anode to cathode

The volume of water can be discharged and exchange with solution as show on Figure 8.

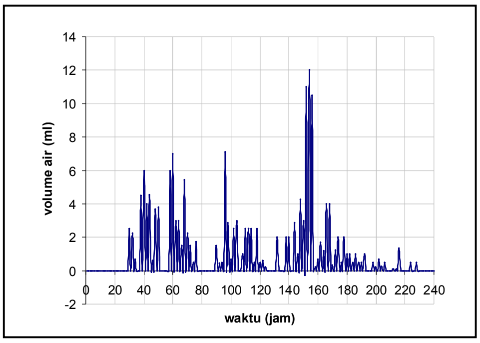


Figure 8. Water discharge from material

Total volume of solution can be discharged from material is 6600 ml but total volume water can be drained is 200 ml.

Electroosmosis Permeability Coefficient

Electro osmoses permeability coefficient (k_e) is the ability of soil to drain water due to electric gradient. Unlike the hydraulic permeability coefficient the value of k_e is not depend on size and relation of soil pore. The value of k_e can be calculate from the model test by recording the drained water volume from cathode in units of time t (q_A), the area of one face side electrode (A) and distance between two electrode (L), and the electrical potential difference (V). The calculation of permeability values using equation (1).

The result of experiment shows, that k_e values decline as long as reducing of degrees of saturated of soil, because of the volume of water that can be drained (dewatering). The value of k_e is $1{,}0107 \times 10^{-5}$ cm/sec Volt.

After this experiment it can be concluded, that the electro osmosis phenomena can transport more effective the cement solution in fine grained soil.

Shear Strength

The shear strength of the sandy clay before and after treatment are obtained from Unconfined Compresive Test and Unconsolidated Undrained Triaxial Test as show on Tabel 4 and 5.

Table 4 Result of Unconfined Compression Test

Parameters	**Before injection**	**After injection**
c_u (kg/cm^2)	0,199	**0,3585**
q_U (kg/cm^2)	**0,3983**	**0,7162**

Table 5 Result of Unconsolidated Undrained Triaxial Test

Parameter	**Before injection**	**After injection**
c (kg/cm^2)	0,0328	**0,018**
Φ (°)	**1,8677°**	**6,9822°**

These results show that the injection of solution Na_2CO_3 2N + $CaCl_2$ 10% to sandy clay was reduce cohesion but instead to increase the internal friction angle (Φ). It meas the properties of clay as fine grained soil was changed as coarse grains soil. In natural kaulinite is clay minerals with two layer sheets. The force atraction and repulsion between clay particles vary at different rates with respect to distance separation. If the net force between particles is attraction, flocs will be formed (flocculated clay). Solution Na_2CO_3 2N + $CaCl_2$ 10% replaced water inter-particles and performed dominant attractive forces.

Mineralogy

By comparing the results of investigation by XRD of soil samples before and after injection shows, that the new compounds Calcium Magnesium Aluminium Silicate Ca-Mg-Al-Si-O are formed (Figure 9). These new compounds are found throughout the soil sample that has been injected by solution. Some amorphous compound are also identified in all electrochemical injected samples.

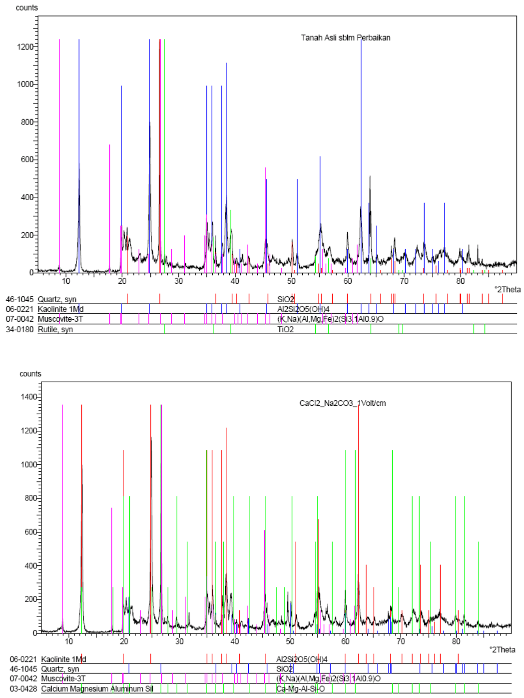


Figure 8 Result of X Ray of soil before threatment (top) and after treatment (bottom)

CONCLUSION

The following conclusion can be drown from the model test. The water in void of soil are replaced by solution with using the electrochemical injection method. The injection of solution Na_2CO_3 2N + $CaCl_2$ 10% to sandy clay are performed new compounds Calcium Magnesium Aluminum Silicate Ca-Mg-Al-Si-O. Eelectrochemical iinjections with solution Na_2CO_3 2N + $CaCl_2$ 10% can increase the internal friction angle of the sandy clay soil, but it decrease the cohesion value.

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