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IMPROVING MARINE CLAYS WITH ELECTROKINETICS METHOD

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ABSTRACT

The high water content in marine clays could loosen the bond of soil particles, resulting in low bearing capacity and high compressibility of the soil. Excessive settlements could happened to the structures built on it. An electrokinetic process was attempted to reduce the high water content of the marine clay. An experimental study was conducted to evaluate the effect of electrokinetic on marine clay improvement. This study focused on the use of electrokinetic to enhance the soil bearing capacity of marine clay by improving index properties of the marine clay. The result of this research was obtained by doing several analyses on water content, pH value, and soil particles of soil sample located between cathode and anode. Based on the results from laboratory testing, it can be concluded that electrokinetic process decreased the water content and pH value of soil surrounding the anode. Also, soil particles surrounding the anode became in close proximity. This indicated that as it became closer to the anode, soil became denser.

Keywords: *electrokinetics, water content, pH value*

INTRODUCTION

Marine clays are often characterized by low shear strength and high compressibility. High water content on the marine clay will caused the marine clay to loose the bond of soil particles and its bearing capacity will decreased. Thus, excessive settlement would happen to the structures built on it. The alternative solutions for this condition are enlarging dimension of its foundation or applying soil improvement.

Recently, there are many significant developments in soil improvement method as the solutions for problems on soft soil of new or existing construction [1]. One of those soft soil improvement methods is the application of electrokinetic to strengthen soft soil bearing capacity [2].

This paper presents results of electrokinetic laboratory experiments without seepage. The goal of the present research is to investigate physical and chemical properties of the marine clay including water content, pH value, and particle structures due to the electrokinetic process.

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ELECTROKINETIC THEORY

In geotechnical engineering, there are many researches of application of electric current to clays in strengthening the soil [2]. This method has an advantage such as application on low permeability soil, fine grained soil, and high pore water soil. Electrokinetic is a soil improvement methods by supplying electric current to electrodes which are embedded in the soil. According to Shang and Materson [3], the improvement of soil characteristics is shown by the increase in shear strength about 69%, shear modulus about 151%, and preconsolidation pressure about 700%. In the next research [4], with the rearrangement of electrodes placement, the foundation bearing capacity increased as great as four times and undrained shear strength of the soil was improved about three times after being continually supplied by a DC current of 5.2 V in 14 days.

The applied electric current leads to electrolysis reactions in the electrodes. Oxidation of water at the anode generates an acid front while reduction at the cathode produces a base front by the following electrolysis reactions [2],

Anode : $2H_2O - 4e^- \rightarrow O_2 + 4H^+$ (1)
Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (2)

The electrolysis reactions are then followed by H^+ migration to the cathode and OH^- migration to the anode, which is called electro migration, and the pore water migration from the anode to the cathode (electro osmotic). The pore water migration would strengthen the soil bearing capacity in the vicinity of the anode.

Several factors are influencing the electrokinetic process as shown in Table 1.

Table 1. The influencing factors in electrokinetic process [5]

Factors		Characteristics
Soil condition	Size of soil particle and type of mineral	▪ Effective on particle size less than 2 m is as 30% or more ▪ More effective on silty clays with moderate plasticity (kaolinite dan illite) rather than high plasticity clays
	Salinity	Not effective on soil with high salinity
	pH	▪ Not effective on soil with low pH value (pH < 6) ▪ Effective on soil with high pH value (pH > 9)
System	Current density	Variation depends on geotechnical characteristic of soil
	Electrodes	Use of metal from silver, platinum, iron, and copper are more effective rather than aluminum, black carbon, and lead
	Configuration of electrodes	Depend on the site condition (pore water flow)

CHARACTERISTICS OF SOIL SAMPLE

In this research, application of electrokinetic method is conducted to marine clay with index properties as stated in Table 2. The initial structure of soil particle is represented by SEM (Scanning Electron Microscope) test as shown in Figure 1.

Table 2. Index Properties of The Marine Clay

Water content (%)	Specific gravity	Liquid limit (%)	Plastic limit (%)	Salinity (g/L)	Soil particles: gravel (%)	Soil particles: sand (%)	Soil particles: fines (%)	Soil classification (USCS)	pH
68.19	2.709	35.41	28.41	17.3	0	26.82	73.28	ML-CL	9.08

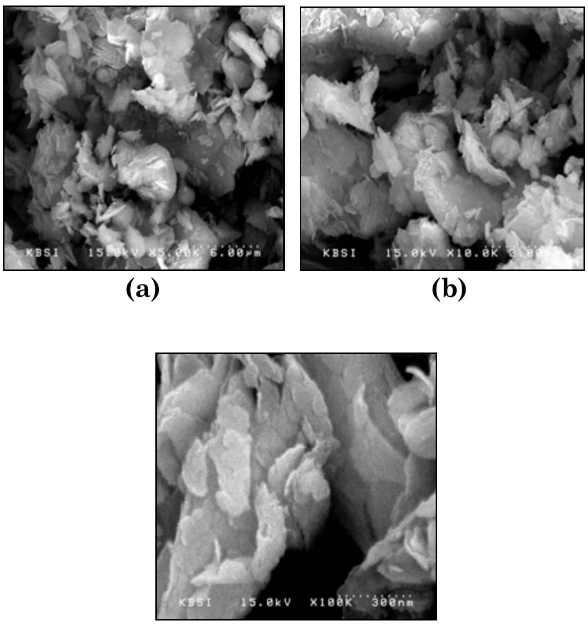


Figure 1. SEM with The Multiply Factor (a) 5000 times, (b) 10000 times, (c) 100000 times

RESEARCH METHODOLOGY AND EXPERIMENTAL PROCEDURE

This research is conducted by supplying a current of 20 volt in the anode and cathodes with duration of three, six, 12, and 24 hours. The anode was a cylinder pile made from stainless steel and the cathodes were made from copper. A schematic experimental setup of the electrokinetic process is presented below (Figure 2). Soil samples were taken at the location (*) of x/L = 0 (anode), x/L = 0.25, x/L = 0.50, x/L = 0.75, and x/L = 1 (cathode) as shown at Figure 2b.

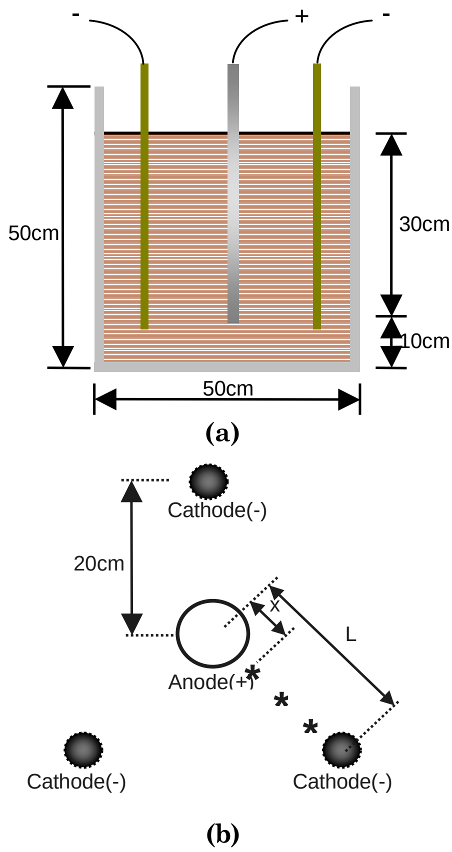
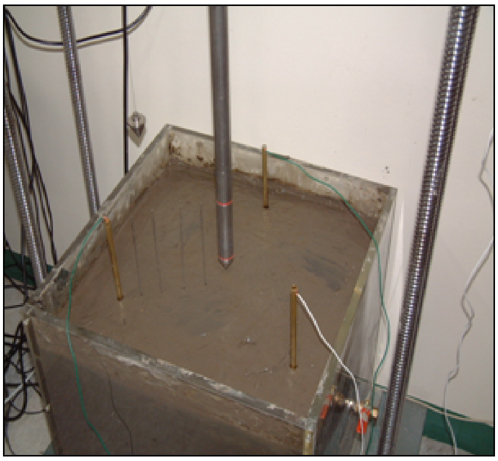


Figure 2. Model (a) and Configuration (b) of The Electrodes in The Soil Sample

This research is conducted by the laboratory testing procedure as follows. Soil is placed in an open 50cm cube Plexiglas box, hand compacted to a volume of 50 x 50 x 40 cm^3. Afterwards the copper pipe as the cathode is embedded into the soil 35 cm deep and the stainless steel anode into 30 cm deep. The electric current was supplied to the electrodes continuously within the specified time duration. In the final stage, several laboratory tests were carried out to investigate the index properties of the soil sample taken at the location of x/L = 0 (anode), x/L = 0.25, x/L = 0.50, x/L = 0.75, and x/L = 1 (cathode) as presented in Figure 2.b. The experimental equipment is depicted in Figure 3.



(a)

(b)

Figure 3. The Experimental Equipment

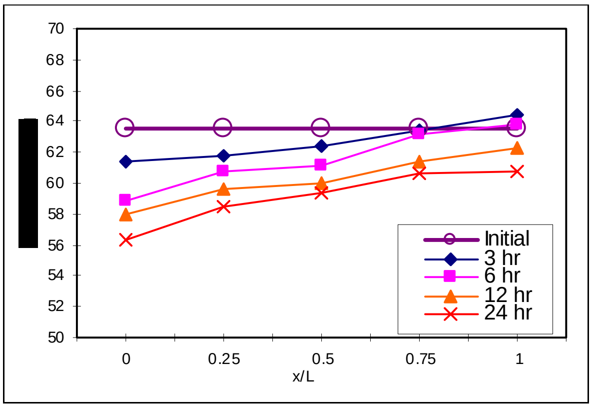
RESULT AND DISCUSSION

The result of this research is obtained by doing several analyses on water content and pH value of soil sample located between the electrodes. An analysis on soil particle structures (SEM test) after electrokinetic process was also conducted to investigate the effects of electrokinetic on the soil improvement.

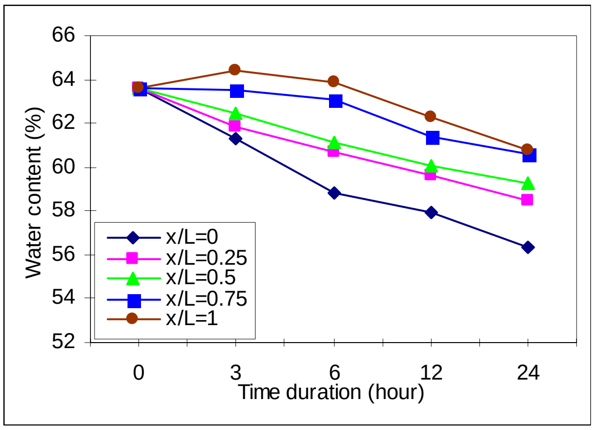
Water Content

The water content, before and after electrokinetic process, is presented in Figure 4. Before the electrokinetic process, the water content at various distances between anode and cathode had the same value. After the electrokinetic process, water moved from anode to cathode, thus the water content at the cathode area (x/L = 1) was higher than at the anode area (x/L = 0) as shown in Figure 4(a).

Besides, the water content was decreasing with the increase of time (Figure 4b). The decreased water content naturally strengthened the soil.



(a)



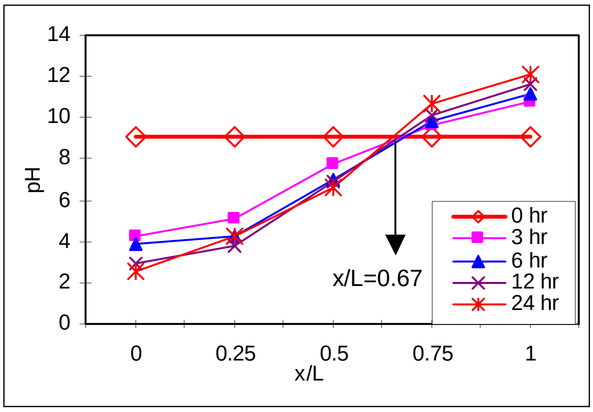
(b)

Figure 4. The water content variation on the location of anode (a) and the time duration (b)

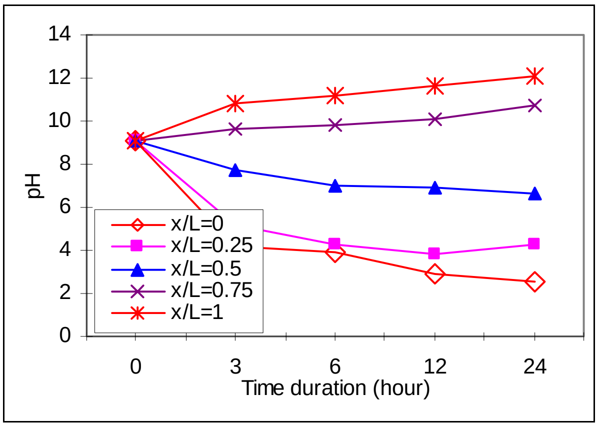
pH

Figure 5 shows the variation in pH value before and after electrokinetic process. As the water moved from the anode to the cathode, pH value at the anode became lower than before the electrokinetic process. On the other hand, pH value at the cathode became higher than before the electrokinetic process.

Therefore as shown in Figure 5, the area surrounding the anode became acid and surrounding the cathode became alkaline. The acid condition caused the corrosion of the metal anode. An interesting phenomena happened at location x/L = 0.67, where pH value was not dependent with the time duration (Figure 5a). At x/L < 0.67, pH value decreased as the increase in time duration, and at the location x/L > 0.67, pH value increased as the increase in time duration.



(a)



(b)

Figure 5. The pH Value Variation on Location of Anode (a) and Time Duration (b)

Scanning Electron Microscope (SEM)

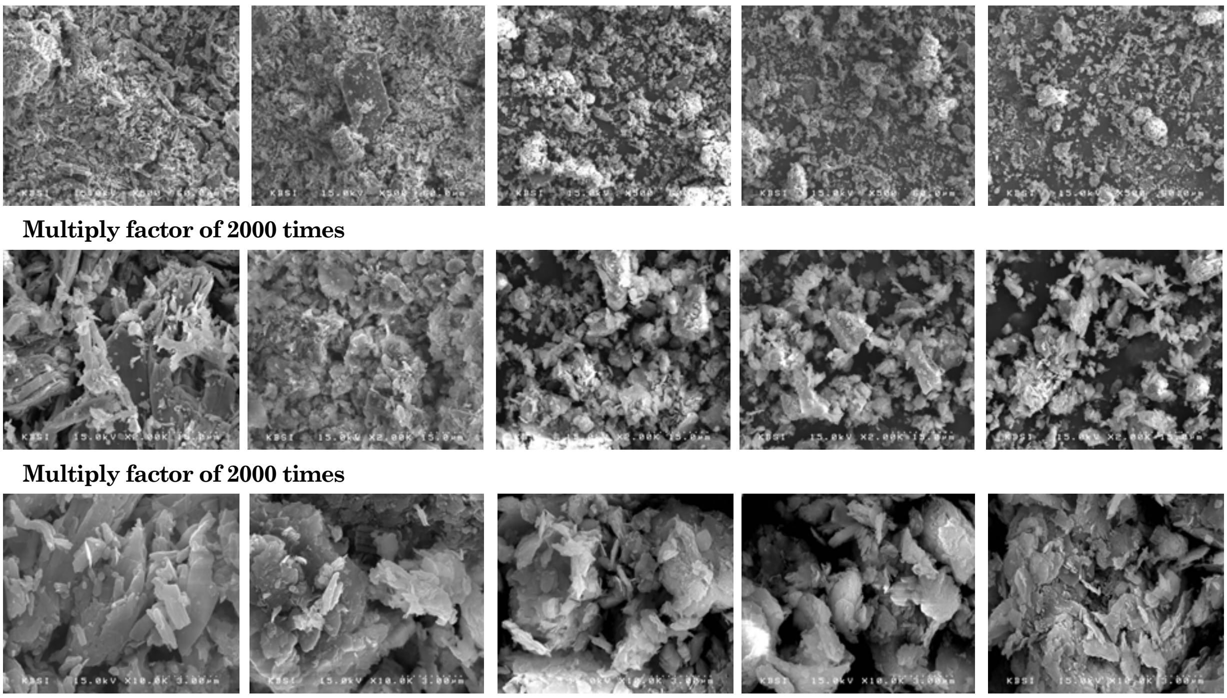
SEM test was conducted on the soil sample located between the anode and the cathode (x/L = 0; 0.25; 0.5; 0.75; 1) to depict soil particle after the electrokinetic process. The soil particles surrounding the anode (x/L = 0) are in close proximity compare to the soil particles surrounding the cathode (x/L = 1). Thus, soil surrounding the anode became denser after the electrokinetic process. This condition is related to the water movement from the anode to the cathode.

CONCLUSIONS

The following is a summary of the conclusion from this experimental study:

1. Electrokinetic process decreased the water content of soil surrounding the anode up to 13%.
2. From the result of SEM test after the electrokinetic process, soil particles surrounding the anode became in close proximity. This indicates that closer to the anode, soil become denser.
3. After electrokinetic process, pH value at the anode decreased up to 257% and at the cathode increased up to 33%. This should be considered in the application of the electrokinetic method, because acid condition surrounding the anode could cause corrosion on the metal of the anode.
4. An interesting phenomena happened at location x/L = 0.67, where pH value was not dependent with the time duration. At x/L < 0.67, pH value decreased as the increase in time duration, and at the location x/L > 0.67, pH value increased as the increase in time duration.

Multiply factor of 500 times



x/L = 0 **x/L = 0.25** **x/L = 0.5** **x/L = 0.75** **x/L = 1**

Figure 5. Scanning Electron Microscope

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