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Cation Exchanges on Stabilized Soft Clay Using Electrokinetic Process

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Abstract: This research study is a part of research of soft clay and expansive clay stabilization with electrokinetic process. The movement of electricity in the clay caused to several phenomena including electrochemistry, electrophoresis, and elektroosmosis. In this study, the author discusses the phenomenon of cation exchange on expansive clays that occur during the electrokinetic process. Exchanger ions in this study is a calcium ions (Ca^{2+}) which is used as a stabilizer. Research carried out on 3 types of soft clay and expansive to get the behavior of cation exchange phenomenon is more valid and complete on clay soil. Electrokinetic process is done by using direct current (DC) with capacity 5 until 10 Volt. Observation of the phenomenon of cation exchange is done by measuring the concentration of calcium ion (Ca^{2+}) and compared to other ion concentration contained in clay for a certain period by using the AAS method (Atomic Absorption Spectrum). The results showed that an increase in the concentration of Ca^{2+} ions in the clay during the electrokinetic process. Increased Ca^{2+} offset by a reduction in other cations, such as sodium (Na^{+}), and pottasium (K^{+}) in the clay. The results could be used as a basic knowledge in developing electrokinetic processes as an alternative to expansive clay stabilization effort.

Keywords: *Cation exchange, electrokinetics process, soft clay, expansive clay, stabilization, lime*

I. INTRODUCTION

The ability of electrons moving inside a conductor media, including clay that has a very high plasticity, is one of the advantages of electrokinetic that can be developed and used in the stabilization effort expansive clays. The movement of electrons during the electrokinetic process causes an electric field and allow the release of charged ions that are bound on the surface of the clay molecules. The effect of charged ions that dislocated on the surface of clay molecules cause of changes equilibrium of the electrical charge in clay soil. To establish equilibrium electric charge, the molecules of clay are known to have a negative charge [1] attract and bind positively charged ions (cations) which are located around the molecule clay. This study was conducted to observe the phenomenon of cation exchange on clay due electrokinetic process.

II. LITERATURE REVIEW

2.1. Clay Soil

Clay is a type of soil that is formed from the weathering of rock core. This soil is composed of several types of minerals, dominated by mineral Silica (SiO_2) and Alumina (Al_2O_3) and has a grain size smaller than 2 mμ [2]. Composition mineral, both of Silica and Alumina of the clay, affect physical properties and mechanical properties of this soil. Comparison of Silica and Alumina in the clay can be a ratio of 1:1 or 2:1. These combination could be forming different types of clay (Fig. 1). The influence of grain size and mineral clay-forming molecules, causing the soil has a very high plasticity properties [1]. Due to the process chemistry, physics and mechanics, clay has a negative charge on the surface of the molecule [3]. To form a greater molecular bond, clay requires a positively charged ions (cations). Cation can be derived from water molecules that have polar properties and also of metal ions. Type and lots of cations that bound to the surface of the clay molecule affects the number of water molecules that can be attracted by clay molecules and also these cation. Lots of water that bound to molecules of cation determine whether the clay is expansive or not.

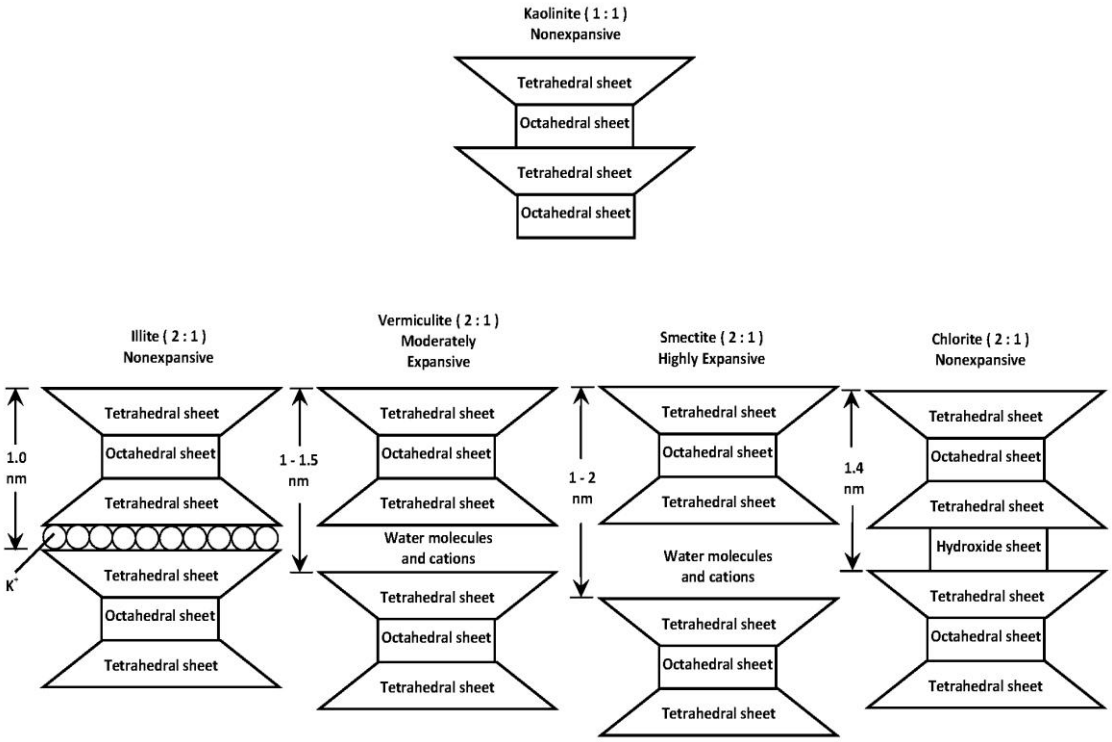


Fig. 1. Some types of clay minerals by comparison bonding silica and alumina at its constituent molecules [1]

2.2. Electrokinetics Process

Electrokinetic is the movement of particles or minerals on a conductor medium that is caused by the electrical. The movement of particles or minerals is caused by an electric field that occurs in media conductor. The electric field in the conductor medium formed by the movement of electrons from the negative (anode) to the positive pole (cathode) [4]. In the basic theory,the movement of electricity in clay can cause phenomena like electrochemical, electrophoresis, elektroosmosis, and also the phenomenon of cation exchange. In real terms this study may also indicate the occurrence of these phenomena, among others, the movement of ions during the electrokinetic process [5] (Fig. 2), and phenomenon of cation exchange [6]. The electric field that formed by the movement of electricity in clay, cause changes electrical charge in the clay. To establish a new equilibrium, molecule of clay need cations. The cations can be obtained from water molecules that have a bipolar nature and also the free cations which are located around the clay molecules. Lime (in the form of solutions, Ca $(OH)_2$) which is used as a stabilizer, due to electrokinetic process undergoes a chemical reaction (electrochemical). If placed in the chamber of negative electrode (cathode), lime will react and produce hydroxyl ions (OH^-), and the calcium ion (Ca^{2+}) if placed in the chamber of positive electrode (anode). The chemical reaction of the aqueous solution of lime (Ca $(OH)_2$) during the electrokinetic process is as follows:

$$\text{Anode} \quad : \quad 2H_2O \rightarrow 4H^+ + O_2 \qquad [1]$$

$$\text{Cathode} \quad : \quad 2H_2O \rightarrow 2(OH)^- + H_2 \qquad [2]$$

The ions formed in the chamber of electrolyte during the electrokinetic process occur, move toward the opposite pole due to the electric field (cations moving towards the cathode (negative pole) and anions move towards the anode (positive pole). The movement of ions (cations and anions) and the imbalance of electric charge on the surface of the clay, cause the binding of new ions on the surface of clay.

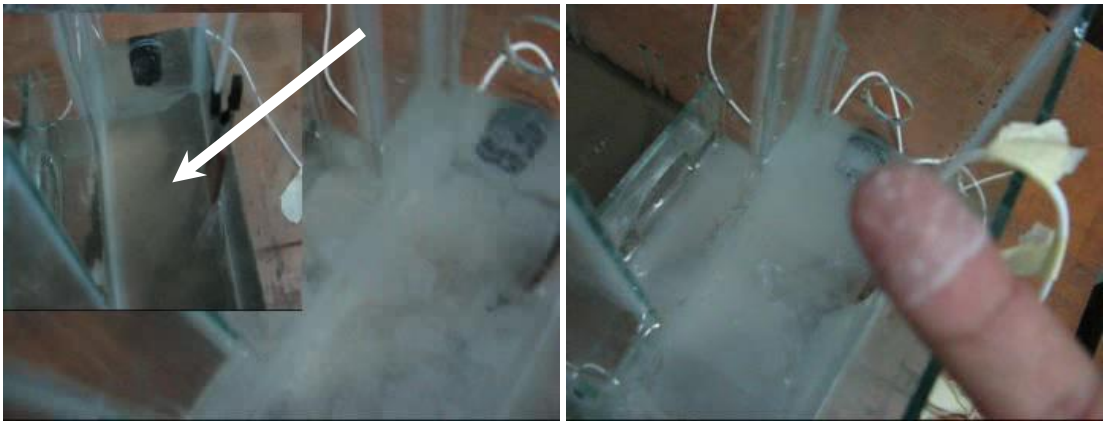


Fig. 2. Visual observation of the movement of ions caused electrokinetics process on clay sample (a). condition at cathode chamber (upper left corner of the image is condition before electrokinetics) (b). traces of lime on the finger [6]

2.3. Cation Exchange

Cation exchange on clay stabilization process with the use of stabilizers, usually influenced by several factors, including: valence of ions, ion size and electronegativity potential of ion. These factors influence the rate of reactivity of an ion, which ions with a higher valence and larger size, able to replace ions with the smaller number valence and size. Ions (cations and anions) have the potential electronegativities to bind the free ion else around, to establish a new equilibrium charge. Potential electronegativity is a chemical property that describes the ability of an atom to attract electrons towards itself in ionic bonds [7]. Sequence of ions based on its reactivity level, compiled from the ions that have a small reactivity to ions that have a large reactivity is as follows [1]: Li^+ - Na^+ - K^+ - Rb+ - Cs^+ - Mg^{2+} - Ca^{2+} - Ba^{2+} - Cu^{2+} - Al^{3+} - Fe^{3+} - Th^{4+}. The sequence of these ions is also known as Volta series. Under terms of the cation exchange, ion which is located to the left of other ions can be replaced by ion on the right. For example Ca^{2+} can replace ions Mg^{2+}, Na^+, K^+, Na^+ and Li^+ (Fig. 3).

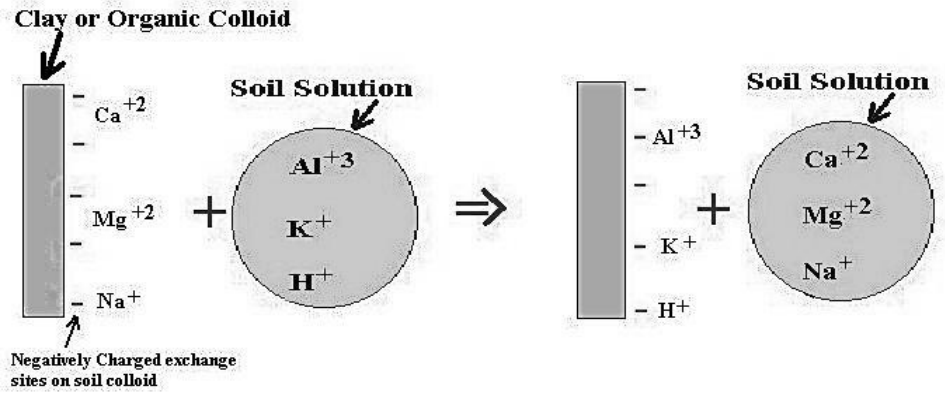


Fig. 3. Analogy of cation exchange on clay particles

In the electrokinetic process, the exchange of cations on the surface of clay accelerated with the advent of the electric field due to the movement of electricity on clay. The electric field causes the electric force that can attracts cations on the surface of the clay. Cations that apart from the surface of the clay leads to changes of the electric charge equilibrium, where the surface of the clay have excess negative charge. To establish a new equilibrium charge, then clay attract cations free which are its around. Stabilizers material (in this case is lime), during the electrokinetic process undergoes a chemical reaction at the positive pole (anode) generates Ca^{2+}. The movement of electrons from the cathode to the anode causes Ca^{2+} ions move towards the cathode. When the speed of Ca^{2+} ions are in ideal conditions (not too fast or too slow), the surface of the clay will draw Ca^{2+} and form new bonds. The phenomenon of cation exchange will be completed if the number of positive charges is relatively similar to the amount of negative charge on the surface of the clay.

III. SCOPE AND LIMITATIONS

The scope of this research was to determine the cation exchange process that occurs in clay during the electrokinetic process. Observations were made toward changes in the concentration of Ca^{2+} ions and other cations which have the potential cation exchange experience during the electrokinetic process occur.

Observations were made on a periodic basis by testing concentrations of cations with Atomic Absorption Spectrometer (AAS) method.

IV. METHODS AND MATERIALS

Research carried out with experimental methods in the laboratory, using 3 types of expansive clay taken from different locations with symbol Clay A, Clay B and Clay C. Electrokinetic process is done by using electrodes made of copper, lime solution, and distilled water (distilled water) as electrolyte. Electricity that used during the electrokinetic process is an electric DC (Direct Current) with a capacity of 5 until 10 Volt. Schematic testing can be seen in Fig. 4 below. Cation exchange was observed by testing the concentration of Ca^{2+} and other cations which have the potential cation exchange experience during the electrokinetic process occur. Observations were made on a periodic basis by testing concentrations of cations with Atomic Absorption Spectrometer (AAS) method. Electrokinetics system that used in this study is by placing main electrodes are connected to the main power supply, and additional electrodes were placed along the clay sample with a certain distance and connected with AVO meter.

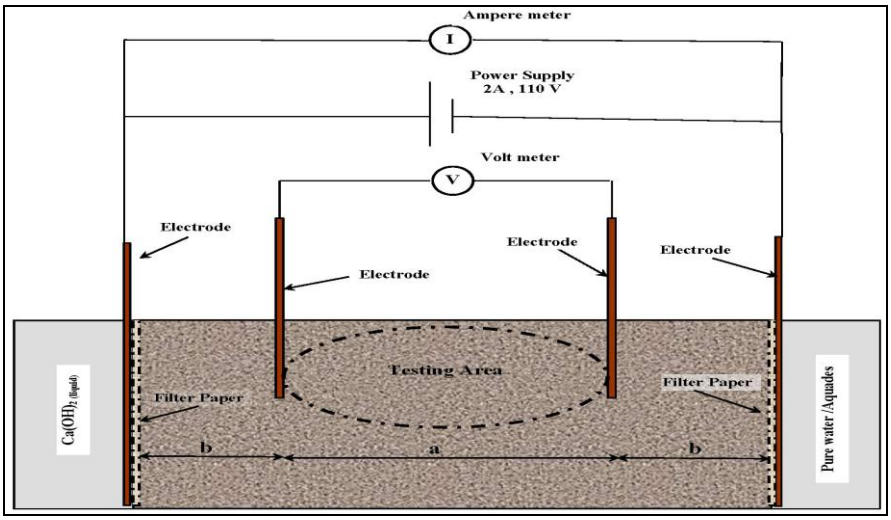
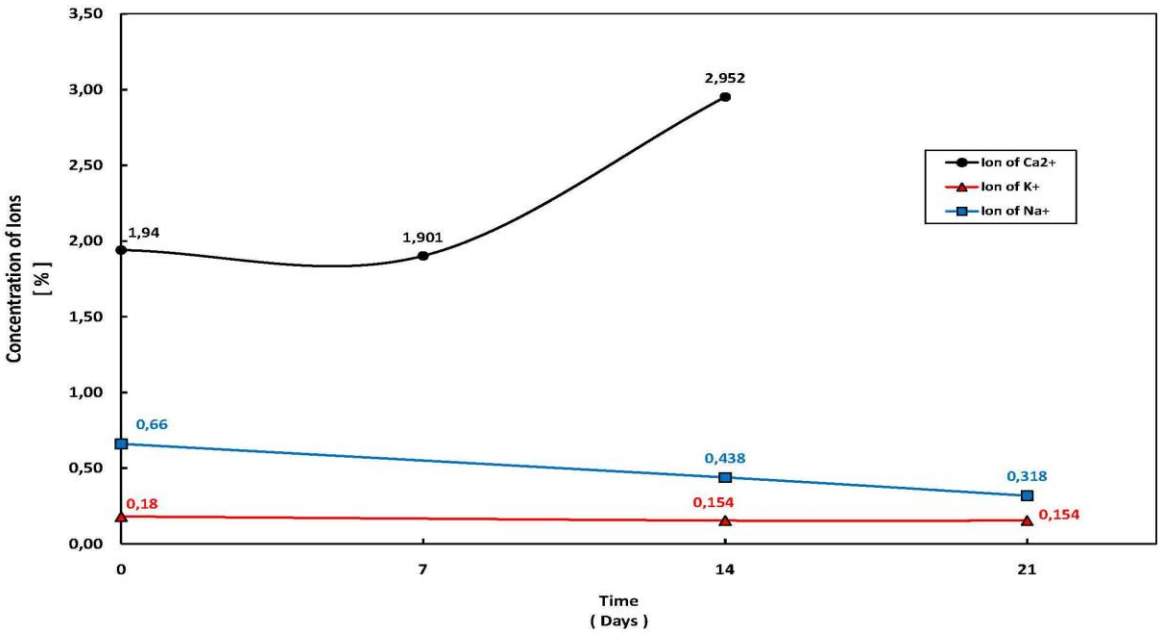


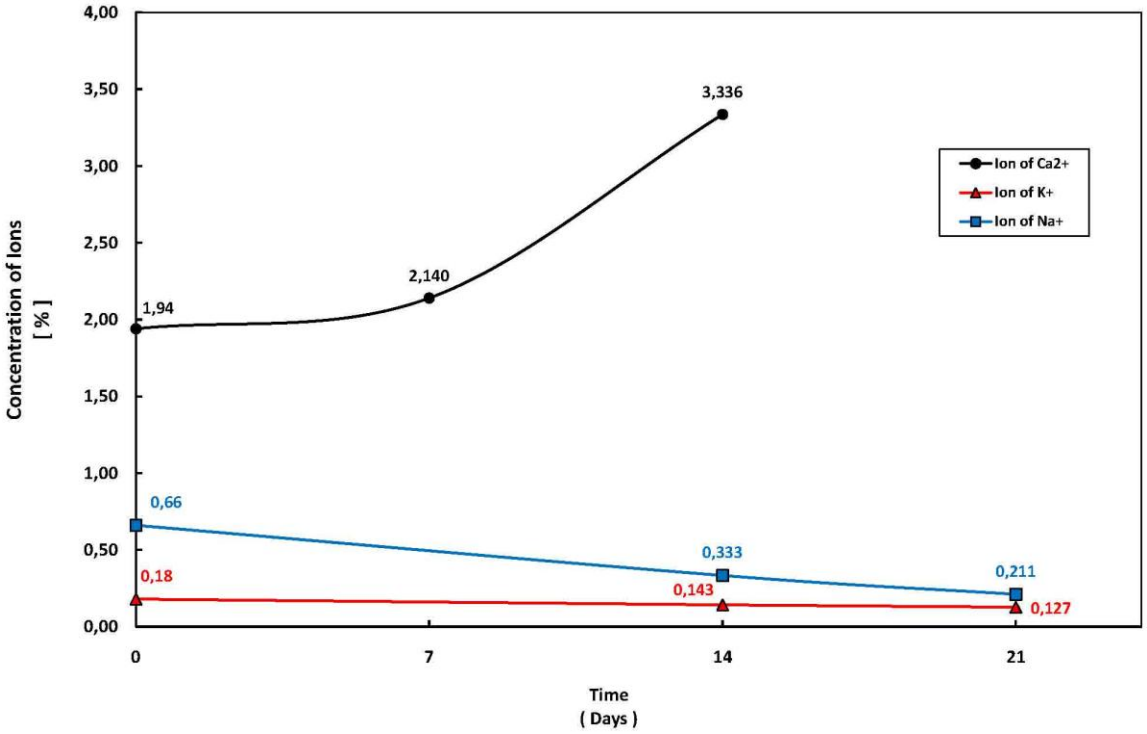
Fig. 4. Schematic of testing of electrokinetics process on expansive clay [6]

V. RESULT AND DISCUSSION

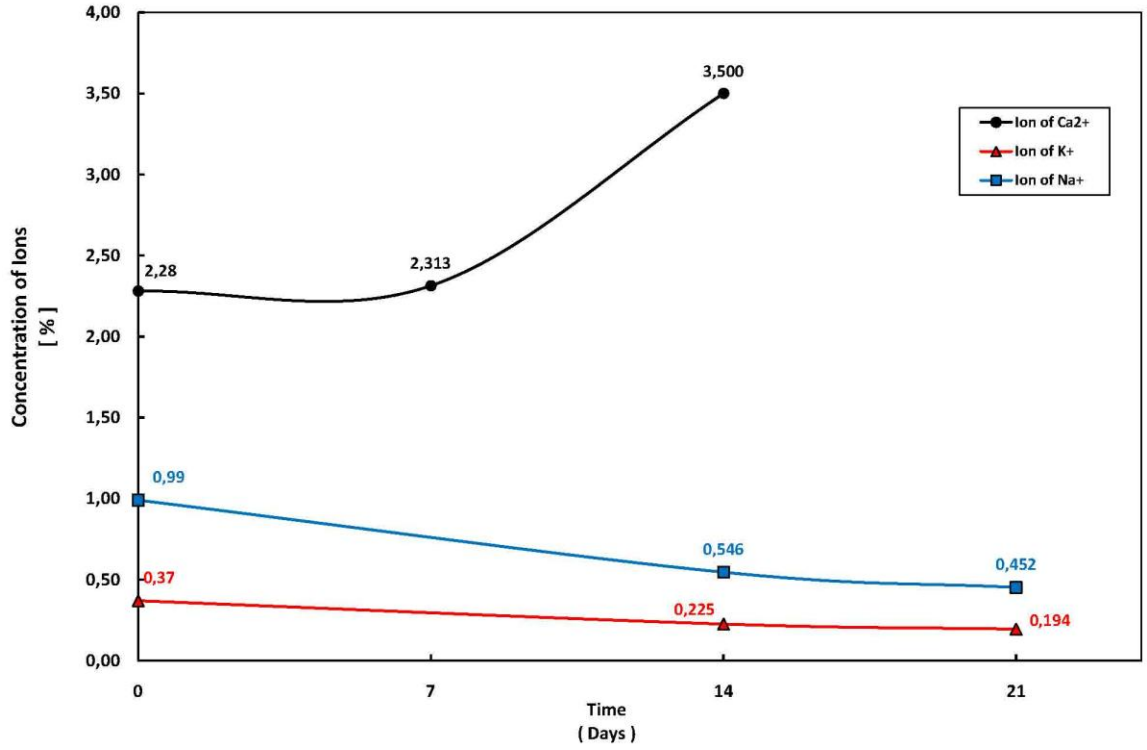
The test results of changes in the concentration of some cations on the clay during the electrokinetic process occurs can be seen in Fig. 5 below.



(**1**)



(2)



(3)

Fig. 5. Step by step the phenomenon of cation exchange on (1). Clay A, (2). Clay B, and (3). Clay C

The test results showed that during the electrokinetic process, occur an increase the concentration of Ca^{2+} ions in clay. Ions are potentially exchanged like ions of K^{+} and Na^{+} had decreased on ion concentration. A decrease in the concentration of ions K^{+} and Na^{+} may be caused by several things, including: electric field that

occurs during the electrokinetic process causing ions K^+ and Na^+ disinterested and detached from the surface of the clay. Another factor that suspected as the cause of the decrease in the concentration of ions K^+ and Na^+ is the clash with Ca^{2+} ions which used as ion exchangers in this study so that the ions K^+ and Na^+ detached from its bond with the molecules of clay. Release of ions K^+ and Na^+ from its bond with the molecules of clay, allowing Ca^{2+} ions attach to and configure of ions bonds with the molecules of clay. The results showed that the cation exchange during the electrokinetic process is really happening.

VI. CONCLUSION

The influence of the movement of electricity during the electrokinetic process, causing the exchange of cations on clay. Cation exchange occur due to changes of electric charges equilibrium that caused by electric field in the clay and clash with Ca^{2+} ions.

VII. ACKNOWLEDGEMENTS

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