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173 ELECTROKINETIC PHENOMENA OF CATION EXCHANGE AND ITS EFFECT ON THE BEHAVIOUR OF EXPANSIVE CLAYS *Nahesson Panjaitan1 and Ahmad Andi2 1&2 Civil Departement, State University of Medan, Indonesia *Coroinho , Received: 21 Oct. 2016, Revised: 20 April 2017, Accepted: 20 May 2017 ABSTRACT: This research is a series study of electrokinetic process that used as an alternative of stabilization effort of expansive clays.

In particular, an observation of the behavioral changes of soil properties and also behavioral changes of soil swell that occur due to the phenomenon of cation exchange during the electrokinatic process were conducted. The cation used in this study was calcium ions (Ca2+) which are derived from the solution of lime which also used as a stabilizer.

Electrokinetic test was conducted by using 2A and 25V DC power. The tested samples in this study were taken from three different locations in Central Java, namely: Purwodadi, Boyolali and Klaten. The composition and concentration of ions in expansive clays was tested by using AAS (Atomic Absorption Spectrum) method.

Behavioral of soil properties known the limits of Atterberg (ASTM 4318 and ASTM 427) from testing while the swelling behavior of soil by testing of swelling (ASTM 4546). The observations against the behavior of clay expansive was at the condition of a change in the concentration of sodium ions (Na+) in the soil during the electrokinetic process.

The results showed that at conditions of the concentration of sodium ions (Na+) was smaller than the initial concentration, the behavior of the value of the liquid limit (LL), the index plastic (PI) and the nature of the development of clay expansive indicated a downward trend, while the behavior of the boundary value shrinkage of the soil showed an upward trend.

The results of this research can be used as a baseline data to the development of electrokinetic as an alternative effort of stabilization expansive clays. Keywords: Electrokinetic, Stabilization, Expansive clay, Cation exchange 1. INTRODUCTION Expansive clay is a type of clay that has the potential of swell and shrinkage that very contrast which due to the effects of changes in water content.

The damages of house and infrastructure caused by swell and shrinkage of expansive clay resulted in a huge amount of losses [1]. In 1980, a number of damages to residential homes and infrastructure damaged in the United States caused by expansive clay reached 7 billion US dollars [2]. Expansive clay spread in almost all the places and areas, such as in the United States, Australia, Canada, India, Israel, Mexico, Venezuela, South Africa, Spain, etc. [3]. In Indonesia, the spread of expansive clay was known from the island of Sumatra up to the island of New Guinea.

On the island of Java in particular, expansive clay known to spread in West Java (Cikampek, Jatibarang and KarangNgampel), Central Java (Kudus, Demak, Godong, Purwodadi, Boyolali, Klaten, Wirosari and Cepu), Yogyakarta (Wates), East Java (Bojonegoro, Babat, Lamongan, Gresik, Ngawi and Caruban) [4]. The study on expansive clay indicate that swelling and the shrinkage of the clay caused by a combination of the main compounds arrangement and developed by their specific cations that have the ability to bind water more than the other cations.

Problems on swelling and shrinkage properties of expansive clay are generally overcome by changed of the soil material, water management (drainage), the use of membranes and the stabilization effort. Complex problems that often occur in the process of stabilization expansive clay are the level of homogeneity of the cations exchange are difficult to achieve, the difficulty in determining the material requirements stabilizers, due to the position of expansive clay that is far from the surface, takes a relatively long period and required expensive cost. This limitation can be solved by using electric moving in a medium called electrokinetic process. 2.

ELECTROKINETIC AND DEVELOPMENT Electrokinetic is a process in which ions (electrons, cations, and anions) move with in a conductor media (including clay) due to the difference in electric potential between the positive pole (anode) and the negative pole (cathode). Beginning with the movement of electrons, which move from the cathode to the anode, causing an electric field in the conductor medium.

The electric field that occurs in the media led to the pull of different ion charge, which cations are attracted to the cathode while anions are attracted to International Journal of GEOMATE, Oct., 2017, Vol.13, Issue 38, pp.173-177 Geotec., Const. Mat. & Env., ISSN:2186-2990, Japan, DOI: https://doi.org/10.21660/2017.38.74846 International Journal of GEOMATE, Oct., 2017, Vol.13, Issue 38, pp.173-177 174 the anode.

In expansive clay, cations that bound on the surface of molecules of clay, which is known to negatively charged, will detach and move toward the cathode [5]. Release of cations from a bond molecular of clay causing equilibrium of electric charge at the surface molecule of clay is changed. To establish a new equilibrium electric charge on the surface of the clay, the cations are located around the clay potentially interested and attached to the surface of the clay. This phenomenon is called to cations exchange.

The basic theory of electrokinetic process on the soil stated by Casagrande (1932), but it was developed by the laboratory scale testing by O'Bannon (1976) by using potassium as a stabilizer [6]. Research development of process electrokinetic in the fields problems of geotechnical, among others: research and observation of the changing nature of the properties (physical) of clay as a result of the electrical-chemical [7], the acceleration of stabilization and consolidation of soft clay [8], the process of purification of contaminated ground water heavy metal Cr (VI) [9], electrical resistivity and the sensitivity of the chemical-physical changes in soil type of peat [10].

Based on the results of previous research that have been done, this research is to continue and develop research of electrokinetic process by observing the behavior of the spread of lime solution on expansive clay using electrokinetic process. 3. POTENTIAL ELECTRONEGATIVITY Potential electronegativity is a chemical property that describes the ability of an atom to attract electrons towards itself in a covalent bond [11]. Atoms consist of a nucleus (neutral charge), protons (positive charge) and electrons (negative charge) moving around the nucleus in its orbit [12].

Coulomb attractive force between electrons and protons causes the electrons bound in atoms [11]. In the condition in which one or a few electrons moving in an orbit of an atom apart due to the interaction force from outside the system, then the atom turns into a cation (surplus positive charge), or vice versa if there are free electrons around the atom, drawn and attached to the system atom, so that the atom has excess negative charge, then the atom turns into anion.

Ions (cations and anions) have the potential electronegativities to bind free ion which exists around them, to establish a new equilibrium charge. For example Ca2+, which has excess 2 positive charge is capable of binding two negatively charged ions such as OH-form a covalent bond Ca (OH)2. 4. ELECTRIC FIELD The electric field is the effect caused by the presence of electric charges, such as electrons, ions, or protons, in a room that is in the vicinity, and can lead to the exchange of electrons in atoms. Exchange of electrons causes electron configuration of atoms can have increased or decreased.

The atom turns into anions (negatively charged ions) when the electrons in the atom increases, while the atomic electrons is reduced from the amount initially will turn into cations (positively charged ions). 5. ELECTROKINETIC PROCESS Electrokinetic process is the movement of electrons from the anode to the cathode as a result of two electrodes implanted on a medium (soil) that generate apotential difference (voltage electricity) [13].

In the soil, electrokinetic process occured by setting of electrodes into the ground and then stream direct current (DC) between the anode and the cathode [14] as shown in Fig.1. Fig.1 Movement analogy of ions caused by the electrokinetic process By the time the two poles of the electrodes; anode (+) and cathode (-) were set into soil and extend potential difference, there will be a movement of electrons and ions (cations and anions) to the electrode (cations towards cathode and anions towards to anode).

During the electrokinetic process, there are some phenomena and a reaction occurs, such as electric field, electrochemical phenomena, electroosmosis, electrophoresis and electromigration [5]. Several phenomena occures as a result of the electrokinetic process as presented in this study, the others from electromigration process as depicted in Fig.2 [15].

International Journal of GEOMATE, Oct., 2017, Vol.13, Issue 38, pp.173-177 175 (a) (b) (c) Fig.2 A visual observation of the movement of ions caused by electrokinetics process on clay sample (a). Condition at cathode chamber before electrokinetics; (b). Condition at cathode chamber after electrokinetics; (c). Traces of lime on the finger [15] 6.

CATIONS EXCHANGES ON CLAY DURING ELECTROKINETIC PROCESS Cation exchange can occur due to a change in the charge on the cation equilibrium caused by the electric field during the electrokinetic process occurred. The moving electrons from the cathode to the anode causing the electric field in the clay. The electric field can lead to the separation of the electrons in the atoms, resulting in a change of equilibrium charge on the atom.

To establish a new equilibrium charge, the atoms form a covalent bond with other ions. Formation of covalent ion bond with the molecular clay influenced by potential of electronegativity certain ion. The greater the potential electronegativity an ion, then the potential of the ionic bonds with the molecules of clay will be greater [16].

On the stabilization of clay with a solution of lime and use the process of electrokinetic, Ca^{2+} is generated as a result of an electrochemical process, have a potential electronegativity larger than the Na^+, K^+ and Mg^{2+}, so all three ions have the potential to be separated from a covalent bond with molecules of clay and replaced with Ca^{2+}. This phenomenon is called the cation exchange. Cation exchange on clay soil does not lead to changes in the molecular structure of the clay (physicochemical).

In addition to comparing the potential value of electronegativity of an atom or element, cation exchange is also affected by valence ion, the type and size of the ion [17]. 7. SCOPE AND LIMITATIONS The scope of this research is to investigate the phenomenon of cation exchange and its influence on the properties of clay and potential for swelling on expansive clay due electrokinetic processes.

Observation to the phenomenon of cation exchange is conducted by using Atomic Absorption Spectrometer (AAS) method to the quantity and composition of clay minerals during the electrokinetic process. Type of main minerals that observed is calcium due to the use of lime in this test. Observations on the properties of clay (liquid limit and shrinkage limit) is conducted by testing the limits of Atterberg (ASTM D4318 and ASTM D427), while the observation of the development potential of clay is conducted by testing swelling (ASTM 4546, (B)). 8.

METHODS AND MATERIALS A DC power source with electrical potential (V) ranges from 5 to 10 volts with the currents (I) is about 2 Ampere was used in this experimental study. All electrodes used in this research were copper material. Media of test that used in this study is an open aquarium made of glass with size (length x width x height): 100 cm x 40 cm x 30 cm.

Electrolyte solution used was a solution of lime that placed in the anode chamber and pure water (distilled water, H_2O) in the cathode chamber. Type of clay tested in this study was taken from three International Journal of GEOMATE, Oct., 2017, Vol.13, Issue 38, pp.173-177 176 different areas in Central Java, namely: Purwodadi, Boyolali, and Klaten. The schematic of electrokinetic testing can be seen in Fig.3. Fig.3

Schematic of electrokinetic testing 9. RESULT AND DISCUSSION Results of testing Atterberg limits, chemical testing and swelling testing of expansive clay that used in this research can be seen in the following table (Table 1).

Table 1 Results of testing Atterberg limits, chemical testing and swelling testing No Type of Testing Type of Soil Purwodadi Boyo lali Klaten 1 Atterberg Limits 1.1 Liquid Limits (%) 71,907 74,731 73,158 1.2 Plastic Limits (%) 34,736 20,95 22,179 1.3 Shrinkage Limits (%) 5,957 6,943 7,563 2 Chemical testing 2.1 Al2O 3 (%) 25,73 19,69 20,20 2.2 SiO 2 (%) 55,84 56,24 62,41 2.3 CaO (%) 2,12 2,72 3,19 2.4 Fe 2O 3 (%) 7,80 16,76 8,72 2.5 MgO (%) 0,78 0,70 1,50 2.6

K 2O (%) 0,42 0,22 0,45 2.7 Na 2O (%) 1,10 0,89 1,33 3 Swelling Test 3.1 Swelling Pressure (kPa) 275 255 235 3.2 Swelling Potential (%) 18,04 17,76 17,54 The results of testing against the changing of soil properties due to changes in the concentration of Ca2+ ions during the electrokinetic process (that shown is the testing of clay Purwodadi) can be seen in Fig.4. (a) (b) (c) Fig.4

Results testing of propertis clay soil from Purwodadi due of electrokinetic process (a). Liquid Limits, (b). Plastic Index, (c). Shrinkage Limits 0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 0.0 0.5 1.0 1.5 2.0 2.5 3.0 (Liquid Limits, LL) (%) [Ca2+] (%) LL and [Ca] values of Purwodadi clay after electrokinetic process LL and [Ca] values of Purwodadi clay before electrokinetic process 0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 0.0 0.5 1.0 1.5 2.0 2.5 3.0

(Plastic Index, PI) (%) [Ca2+] (%) PI and [Ca] values of Purwodadi clay after electrokinetic process PI and [Ca] values of Purwodadi clay before electrokinetic process 0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 0.0 0.5 1.0 1.5 2.0 2.5 3.0 (Shrinkage Limits, SL) (%) [Ca2+] (%) SL and [Ca] values of Purwodadi clay after electrokinetic process SL and [Ca] values of Purwodadi clay before electrokinetic process International Journal of GEOMATE, Oct., 2017, Vol.13, Issue 38, pp.173-177 177 The swelling test results (pressure swell and potential swell) of clay due to changes in the concentration of Ca ions during the electrokinetic process can be seen in the table below. (Table 2) Table 2.

The swelling test results of expansive clay No Parameters Values of Parameters Purwodadi 1 [Ca2+] (%) 0,7 42 2, 462 2 Swelling Potential (%) 10,13 8,63 3 Swelling Pressure (kPa) 147 128 Table 2. (continued) No Parameters Values of Parameters Boyolali Klaten 1 [Ca2+] (%) 0,380 2,414 0,944 3,634 2 Swelling Potential (%) 11,42 8,13 11,55 8,35 3 Swelling Pressure (kPa) 159 121 151 113,3 10.

CONCLUSION The test results of the properties of clay showed that the electrokinetic process is capable of lowering the value of the Liquid Limit (LL) and Plasticity Index (PI) and increase the value of shrinkage limit of clay. On the condition of the concentration of Ca2+ less than the value of the initial concentration of Ca2+, the value of the liquid limit and plasticity index of clay was much diminished compared with the value of the liquid limit and plasticity index of the original land while the value of Shrinkage Limit (SL) in these conditions is greatly increased compared to the value of the original soil shrinkage limit.

It is caused by changes in the concentration of ions that are on expansive clay after electrokinetic. The test results of swelling clay indicated the decline in value against the swelling pressure and swelling potential of expansive clay. The similar results as on result of the properties of soil, on condition of concentration value of Ca2+ ion, is smaller than the original value of clay, the value of swelling pressure and swelling potential of clay is under swelling pressure value and potential swelling of the original clay.

The experimental results showed that electrokinetic process could be a potential alternative of stabilization process expansive clay. 11. REFERENCES [1] Joes, D. E.d Ho G. “Expsive Sil - the hend Civil Engineering – ASCE , 43 (8), 1973, 49-51. [2] Wray, W. K., dan Meyer, K. T., “Expsive y SilA esp d stly Hazard, GeoStrata, ASCE GeoInstitute , 2004, 24-28. [3] Ch enFH., FodnonExpsive oil 1st ed. Vol.

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